

GROUNDWATER INVESTIGATION AND REMEDIATION

Introduction

During 2001, groundwater investigations and remediations under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) continued at both the Livermore site and Site 300. LLNL regularly samples and analyzes groundwater from areas of known or suspected contamination. Portions of the two sites that contain groundwater with concentrations of chemicals of concern are actively investigated to determine the magnitude of the contamination and its source. Remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each study area is developed in consultation with the regulatory agencies and the community.

This chapter reviews the distribution of contaminants in groundwater, and the progress LLNL has made in removing contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site and Site 300.

Livermore Site Groundwater Project

Physiographic Setting

The general topography of the Livermore site is described in Chapter 1. The Livermore Valley groundwater system is a sequence of semiconfined aquifers

in which groundwater moves downslope from the valley uplands toward the east-west axis of the valley. It then flows generally westward toward the southwest portion of the basin. From there, groundwater has historically flowed south into the Sunol Valley Groundwater Basin.

The largest quantities of groundwater are pumped from the central and western portions of the Livermore Valley, where the valley fill sediment is thickest. These sediments make up two aquifers: the Livermore Formation and its overlying alluvium.





The Livermore Formation averages about 1000 m in thickness and occupies an area of approximately 250 km². The alluvium, which is about 100 m thick, is the principal water-producing formation within the valley.

Hydrogeology

Sediment types at the Livermore site are grouped into four categories—clay, silt, sand, and gravel—based on the dominant particle type. Groundwater flow beneath the site is primarily in alluvial sand, gravel lenses, and channels, bounded by the less permeable clay and silt.

The alluvial sediments have been mapped into seven hydrostratigraphic units (HSUs) beneath the Livermore site, using data collected over the years. HSUs can be defined as sedimentary sequences whose permeable layers show evidence of hydraulic connection. The HSUs of concern beneath the Livermore site are the Quaternary alluvial deposits of the upper Livermore member of the Livermore Formation (see [Figure 8-1](#)). HSUs 1B, 2, 3A, 3B, 4, and 5 contain contaminants that are primarily solvents (Blake et al. 1995; Hoffman et al. 1998).

Background

Initial releases of hazardous materials occurred at the Livermore site in the mid-to-late 1940s when the site was the Livermore Naval Air Station (Thorpe et al. 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed volatile organic compounds (VOCs), fuel hydrocarbons (FHCs), lead, chromium, and tritium to the groundwater and unsaturated sediment in the post-Navy era. The Livermore site was placed on the Environmental Protection Agency (EPA) National Priorities List in 1987.

A screening of all environmental media showed that groundwater and unsaturated sediment are the only media that require remediation (Thorpe et al. 1990). The identified compounds that currently exist in groundwater at various locations beneath the site at concentrations above drinking standards are trichloroethylene (TCE), perchloroethylene (PCE), 1,1-dichloroethylene (1,1-DCE), chloroform, 1, 2-dichloroethylene (1,2-DCE), 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), trichlorotrifluoroethane (Freon 113), trichlorofluoromethane (Freon 11), and carbon tetrachloride.

Remedial Activities

In 2001, the Livermore site Groundwater Project (GWP) treated more than 1056 million liters of groundwater and removed approximately 142 kg of volatile organic compounds (VOCs). The GWP also brought new treatment facilities on line, installed wells, conducted hydraulic tests, developed groundwater models, published required documents, and maintained close contact with regulatory agencies and the community.

LLNL removes contaminants from groundwater and from the unsaturated zones (soil vapor) at the Livermore site through a system of 27 treatment facilities located throughout the 6 HSUs containing contaminants of concern. Within each facility, extraction wells are used to extract groundwater, which is then treated to remove VOCs.

Treatment usually consists of removing VOCs with a large capacity air-stripping system, after which any VOCs present in the stripper's effluent air are removed with granular activated carbon filters. Methods are noted in the following discussion of treatment facilities. [Table 8-1](#) lists the extraction wells, according to the HSU in which they are screened, and the total flow rate for each treatment area.

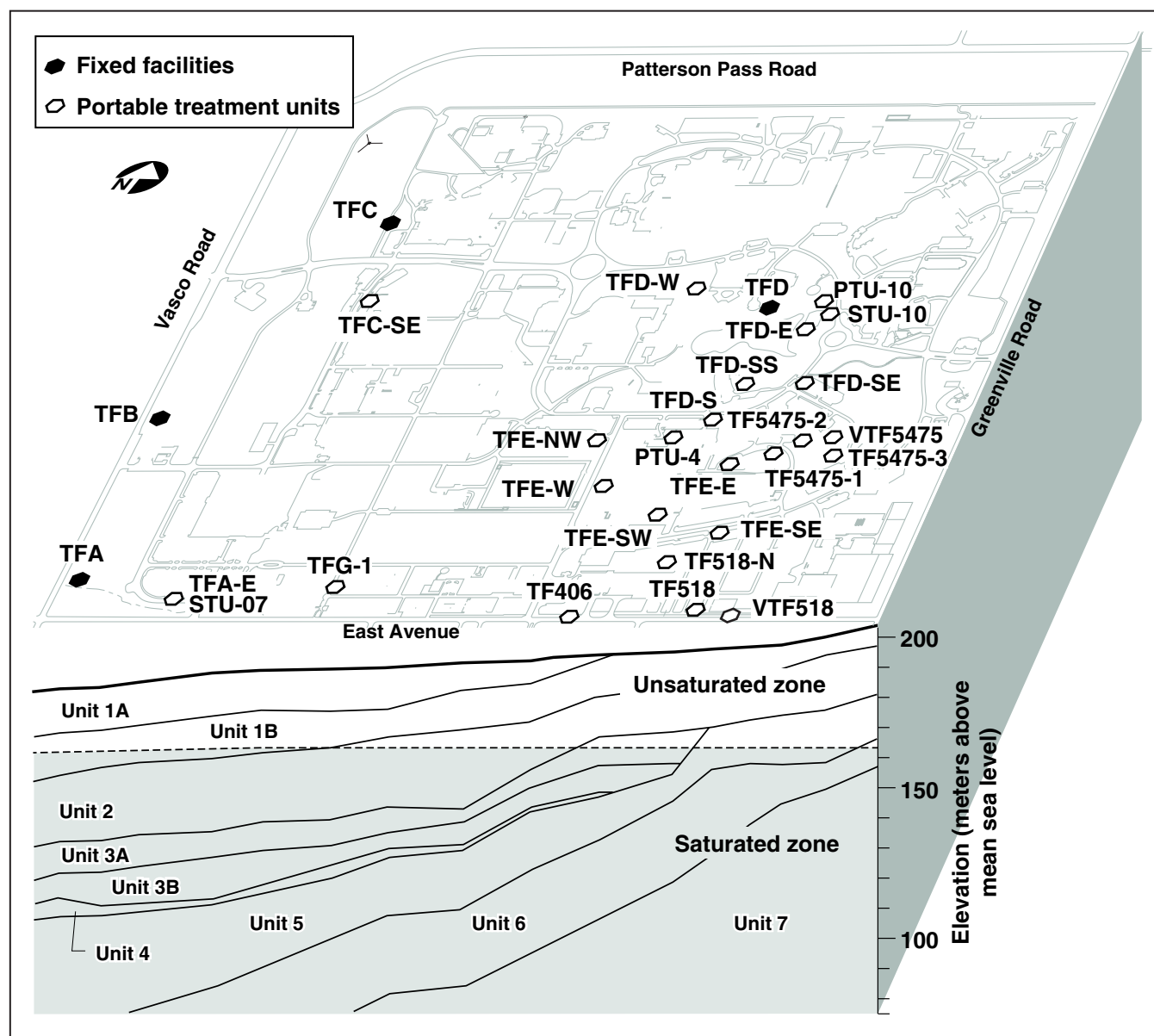


Figure 8-1. Map and cross section of the Livermore site showing hydrostratigraphic units and the locations of the treatment facilities

Of the 27 treatment facilities, 25 are groundwater treatment facilities and 2 are vapor treatment facilities (VTFs). A total of 77 groundwater extraction wells operated at 25 separate locations at an average flow rate of 2540 liters per minute (L/min). A total of two vapor extraction wells operated at two separate locations at an average flow rate of 672.24 m³/min.

Since operations began in 1989, approximately 6544 million liters of groundwater and more than 924,000 m³ of vapor have been treated, and more than 1238 kg of VOCs have been removed.

Table 8-2 shows both the 2001 totals and the cumulative totals of groundwater and soil vapor treated at the facilities and the estimated VOCs removed from the subsurface. A graph of VOC



Table 8-1. 2001 extraction wells and extraction rates

Treatment facility area	Hydrostratigraphic Unit	Extraction wells	Average extraction rate (L/min) ^(a)
TFA	HSU 1B	W-254, W-262, W-408, W-520, W-601, W-602, W-1001, W-1004	946.4
	HSU 2	W-109, W-415, W-457, W-518, W-522, W-603, W-605, W-609, W-614, W-714, W-903, W-904, W-1009	
	HSU 3A	W-712	
TFB	HSU 1B	W-610, W-620, W-704	223.3
	HSU 2	W-357, W-621, W-1423	
TFC	HSU 1B	W-701, W-1015, W-1102, W-1103, W-1104,	143.8
	HSU 2	W-1213	
TFD	HSU 2	W-906, W-1215, W-1216, W-1303, W-1306, W-1308, W-1510, W-1550, W-1602, W-1603	526.2
	HSU 3A/3B	W-1208, W-1301, W-1504, W-1551, W-1552, W-1601, W-1651, W-1654	
	HSU 4	W-314, W-351, W-1206, W-1307, W-1503, W-1523	
	HSU 5	W-907	
TFE	HSU 2	W-1109, W-1409, W-1518, W-305	238.5
	HSU 3A/3B	W-1422, W-1522, W-292	
	HSU 4	W-1211, W-1418, W-1520	
	HSU 5	W-359, W-566	
TF406	HSU 4	W-1310	76.5
	HSU 5		
TFG	HSU 1B/2	W-1111	10.6
TF518	HSU 3B/4	W-1410	12.1
	HSU 5		
VTF518		SVB-518-204	0.0057 (scmm) ^(b)
TF5475	HSU 2	W-1415	0.72
	HSU 3A	W-1302, W-1606, W-1608	
	HSU 5	W-1610	
VTF5475		SVI-EST-504	0.46 (scmm)

a L/min= Liters per minute

b scmm = Standard cubic meters per minute

Table 8-2. Volatile organic compounds (VOCs) removed from groundwater and soil at the Livermore site

Treatment facility ^(a)	Startup date	2001		Cumulative total	
		Water treated (ML) ^(b)	VOCs removed (kg)	Water treated (ML)	VOCs removed (kg)
TFA	9/89	408	10.2	3468.6	147
TFB	10/90	117.3	6.9	662.4	52.2
TFC	10/93	75.7	7.2	858.5	47.3
TFD	9/94	276.3	90	1229.1	432
TFE	11/96	124.9	25.4	438.7	121
TFG	4/96	5.7	0.3	57.9	3.0
TF406	8/96	37.9	0.9	174.9	6.7
TF518	1/98	12.1	0.7	32.2	3.7
TF5475	9/98	0.379	1.1	1.6	4.2
Total ^(c)		1058	143	6924	817
		Soil vapor treated (10 ³ m ³)	VOCs removed (kg)	Soil vapor treated (10 ³ m ³)	VOCs removed (kg)
VTF518 ^(d)	9/95	2.94	2.6	425	153
VTF5475 ^(d)	1/99	240.7	70.2	516	268
Total ^(c)		244	73	941	421

a Includes fixed and portable units

b ML = 1 million liters

c Totals rounded to nearest whole number

d Vapor treatment facility

mass removal at the Livermore site since 1989 is presented in [Figure 8-2](#). Concentrations of total VOCs in the third quarter 2001 are depicted as isoconcentration maps in the six HSUs in [Figures 8-3](#) through [8-8](#). The VOC plumes in HSUs 1B, 2, 3A, 3B, 4, and 5 continue to be hydraulically controlled based on trends in groundwater chemistry, capture zone analysis, and the total VOC isoconcentration maps for each HSU ([Figures 8-3](#) through [8-8](#)).

The numbers and associated treatment facility areas of new wells installed in 2001 are shown in [Table 8-3](#). Well construction details, well closure data, and results of drawdown tests are provided in

the *LLNL Groundwater Project 2001 Annual Report* (Dibley et al. 2002).

Treatment Facility A

Treatment Facility A (TFA) is a fixed facility located in the southwestern quadrant of the Livermore site near Vasco Road and East Avenue ([Figure 8-1](#)). Groundwater is treated using the large-capacity air-stripping system installed in June 1997. VOCs are stripped from the groundwater, and the effluent air from the stripper is passed through granular activated carbon filters to remove VOCs. The treated effluent air is then vented to the atmosphere.

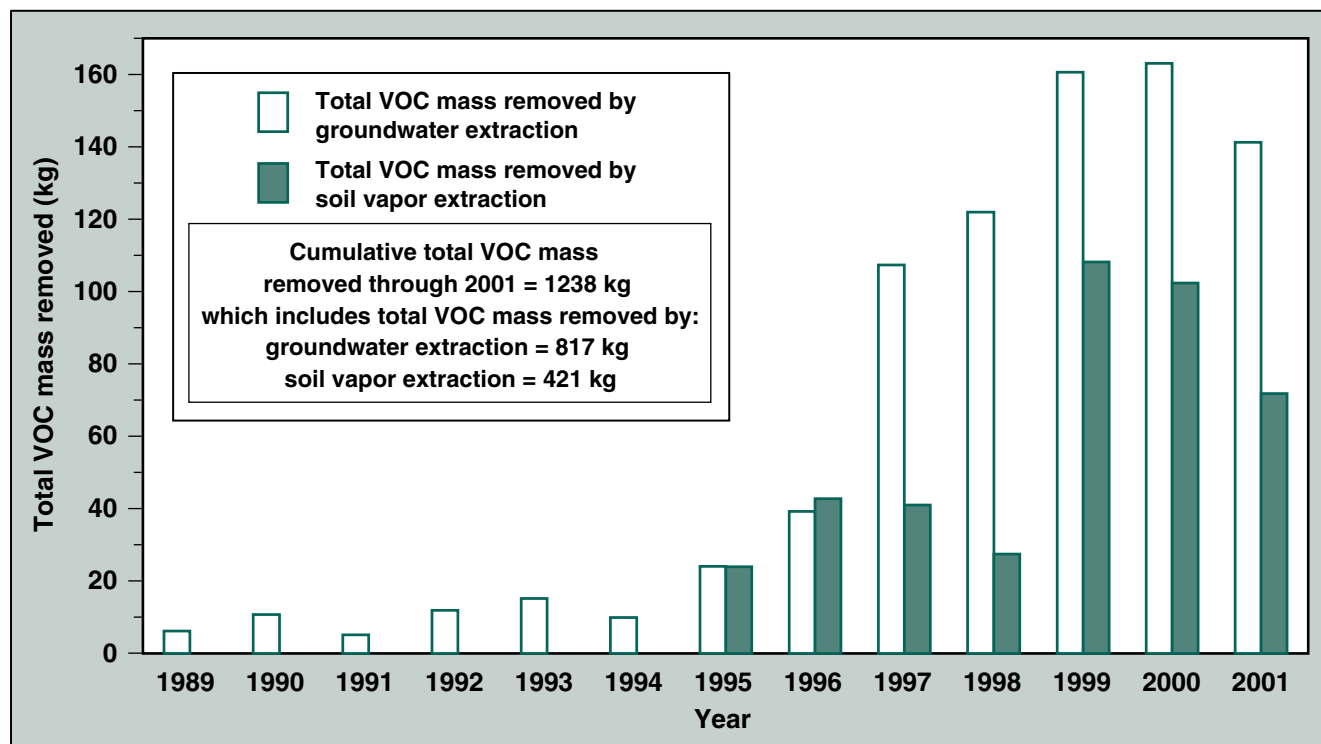


Figure 8-2. Total VOC mass removed from the subsurface of the Livermore site, 1989–2001

The San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) permits LLNL to treat up to 1890 L/min of groundwater. Treated groundwater from TFA is discharged to the Recharge Basin, located about 600 m southeast of TFA on Department of Energy (DOE) property administered by Sandia National Laboratories/California (Sandia/California). Since the startup of the new system, TFA has not exceeded the 5 parts per billion (ppb) total VOC discharge limit.

Solar treatment unit (STU) TFA East (TFA-E) is located east of TFA and processes VOCs in groundwater using granular activated carbon. TFA-E was in compliance with all permits through 2001.

In 2001, wells at TFA and TFA-E pumped at a combined flow rate of about 776 L/min and treated 408 million liters of groundwater containing an estimated 10.2 kg of VOCs.

One new monitor well (W-1701) was installed in the TFA area in 2001 (see [Table 8-3](#)).

Treatment Facility B

Treatment Facility B (TFB) is located in the west-central portion of the Livermore site ([Figure 8-1](#)). Groundwater is treated using the large-capacity air-stripping system installed in October 1998. This unit replaced an ultraviolet/hydrogen peroxide (UV/H₂O₂) system that had been in use since 1990. Groundwater is also treated for chromium(VI) in an ion-exchange unit, during December through March, based on the current

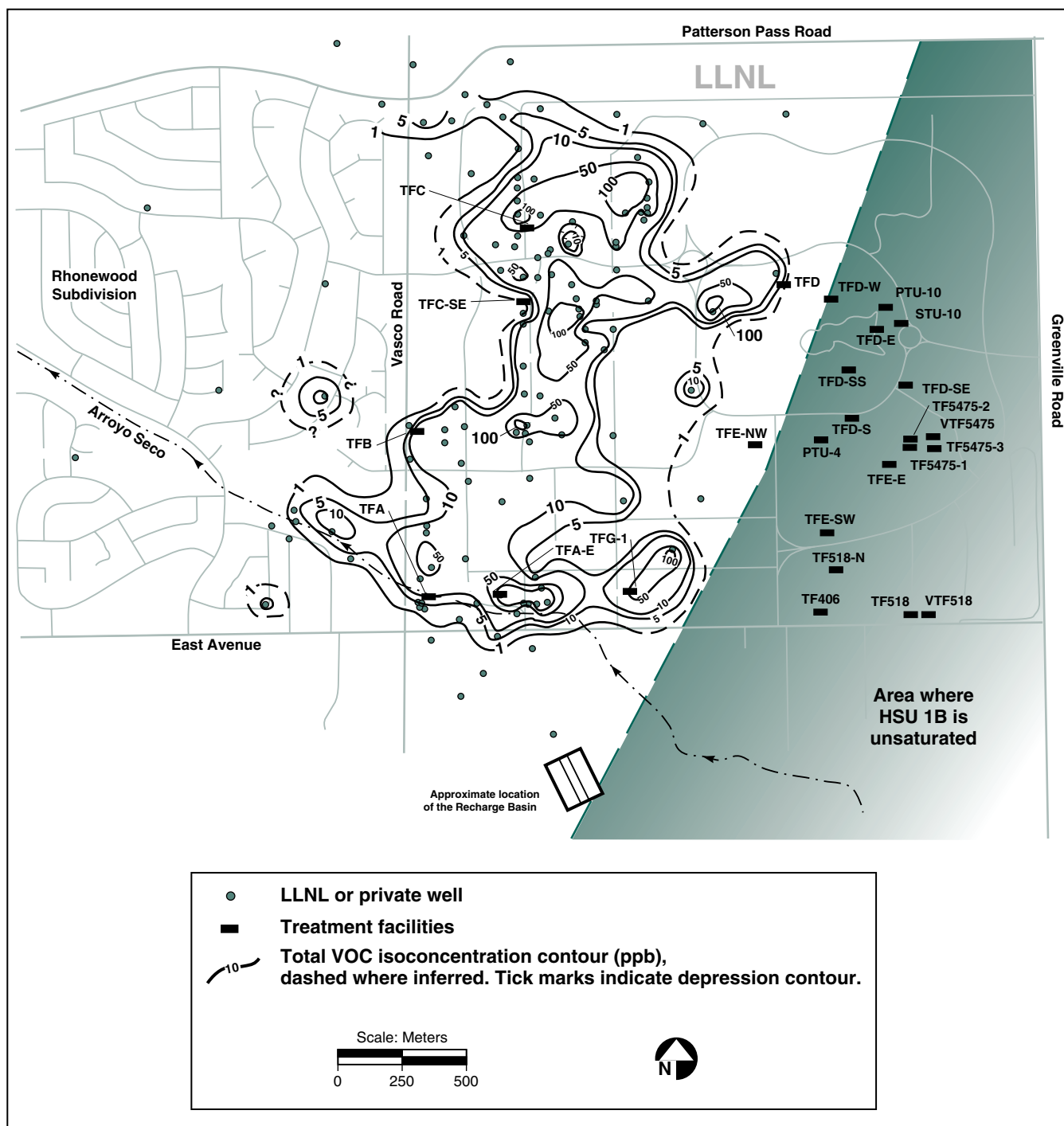


Figure 8-3. Isoconcentration contour map of total VOCs within HSU 1B, 2001

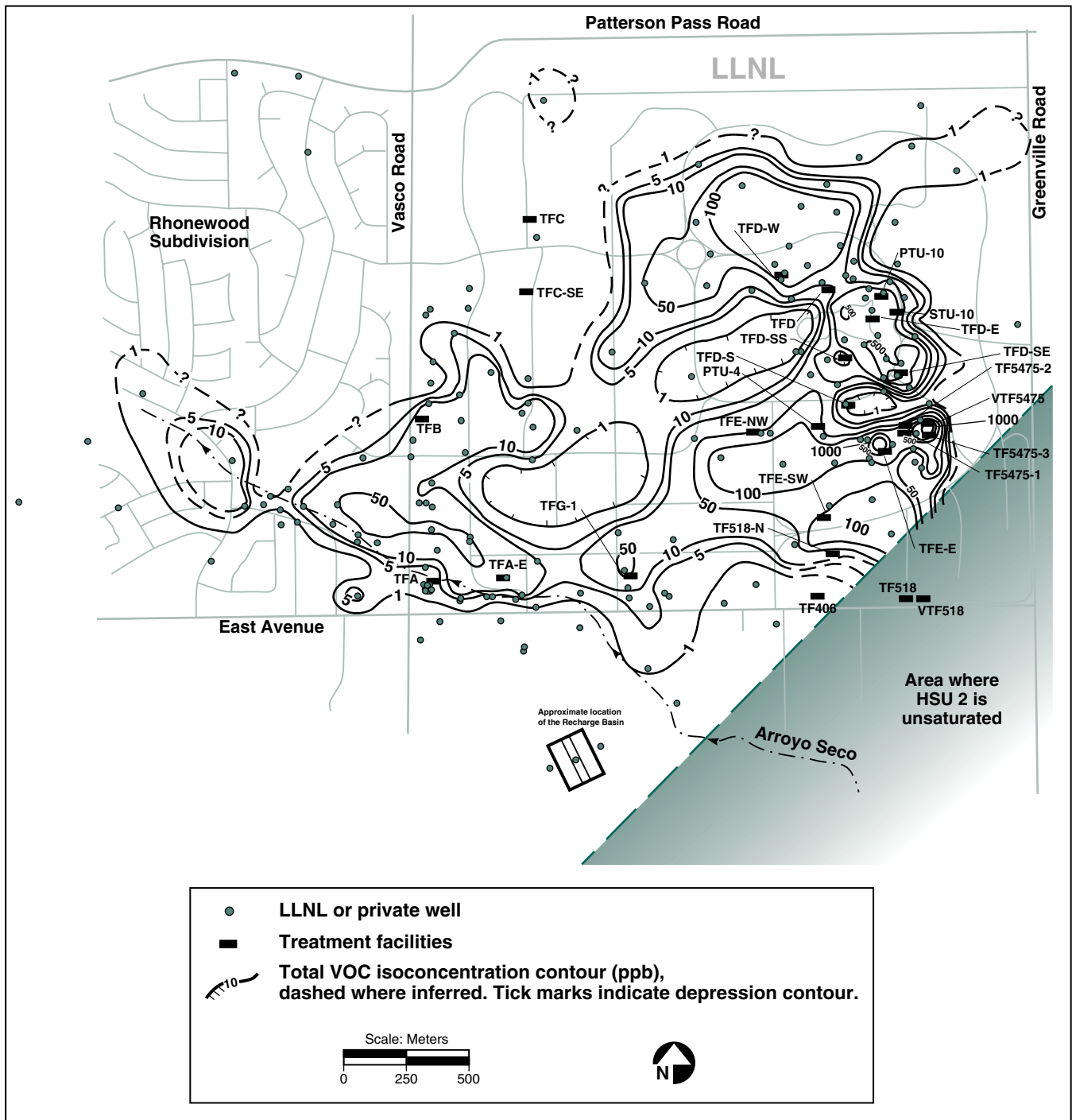


Figure 8-4. Isoconcentration contour map of total VOCs within HSU 2, 2001

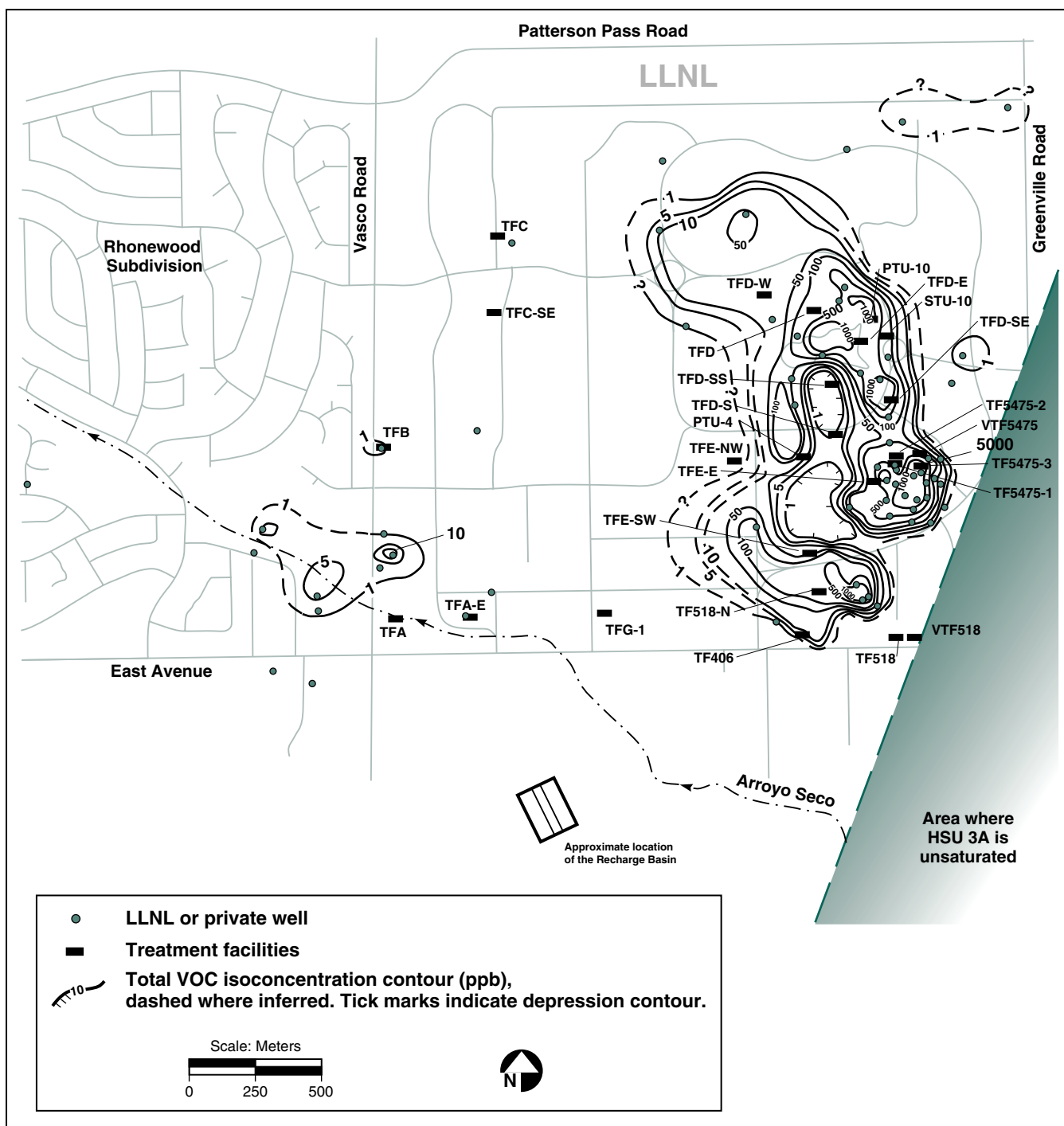


Figure 8-5. Isoconcentration contour map of total VOCs within HSU 3A, 2001

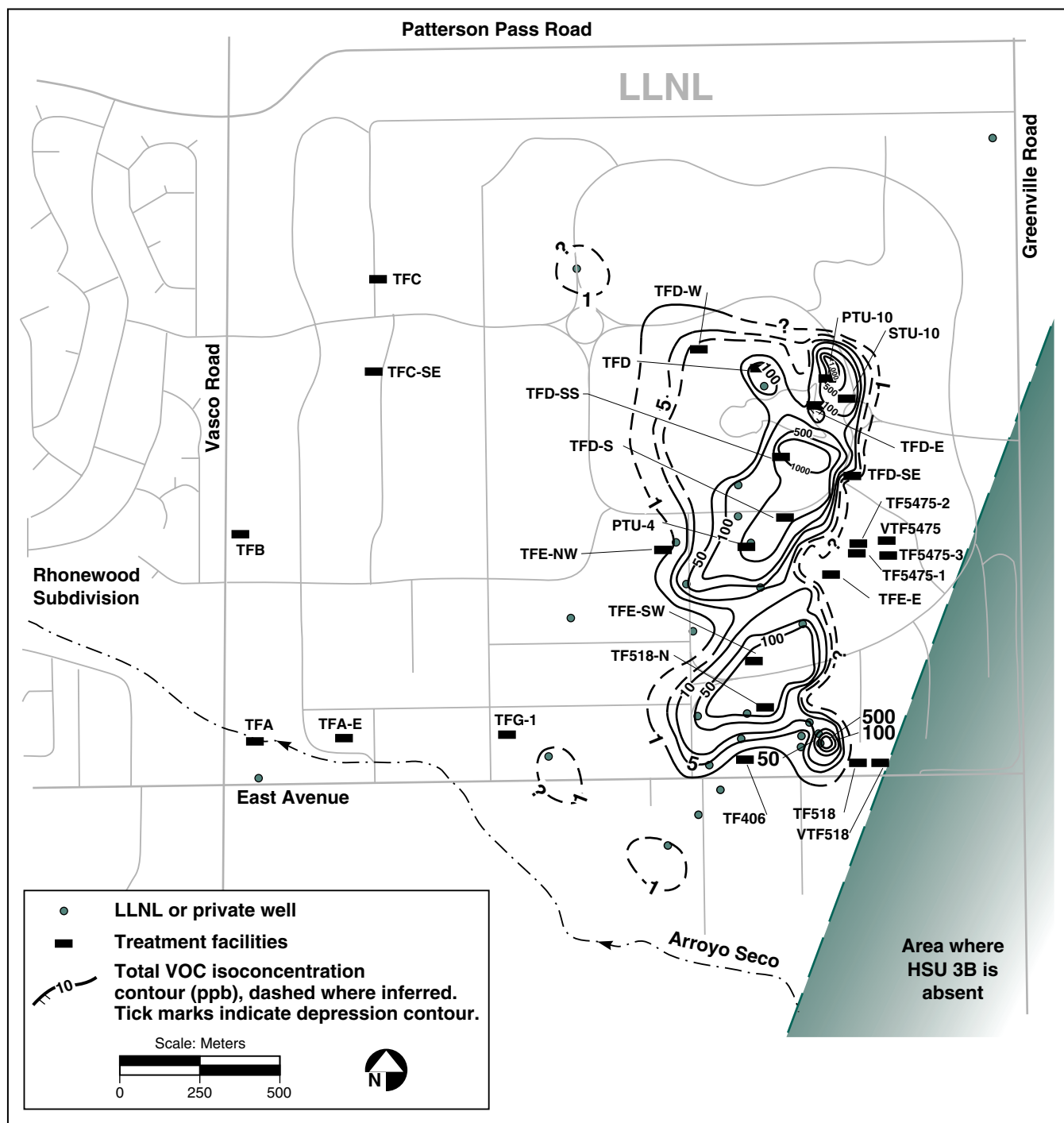


Figure 8-6. Isoconcentration contour map of total VOCs within HSU 3B, 2001

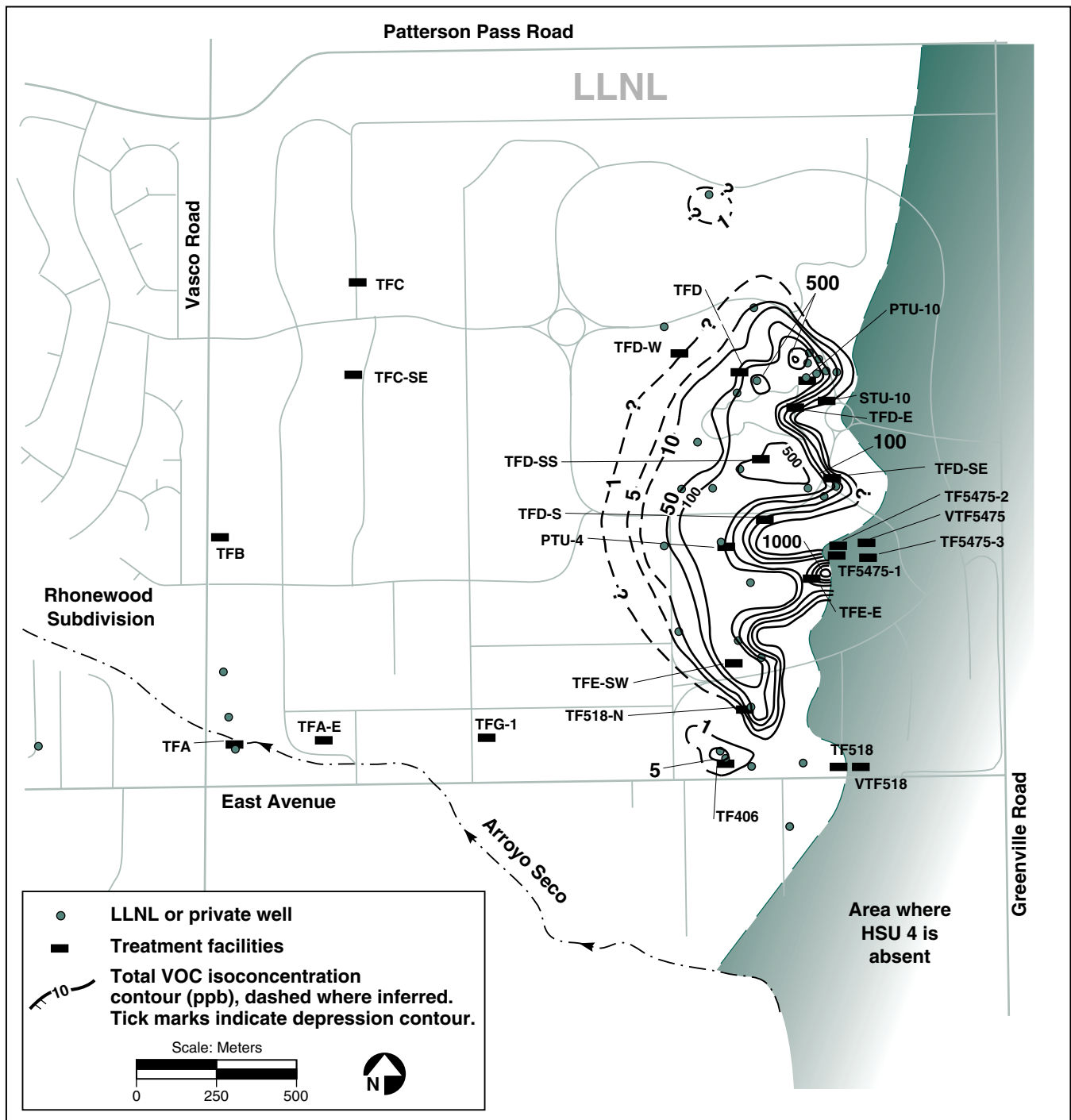


Figure 8-7. Isoconcentration contour map of total VOCs within HSU 4, 2001

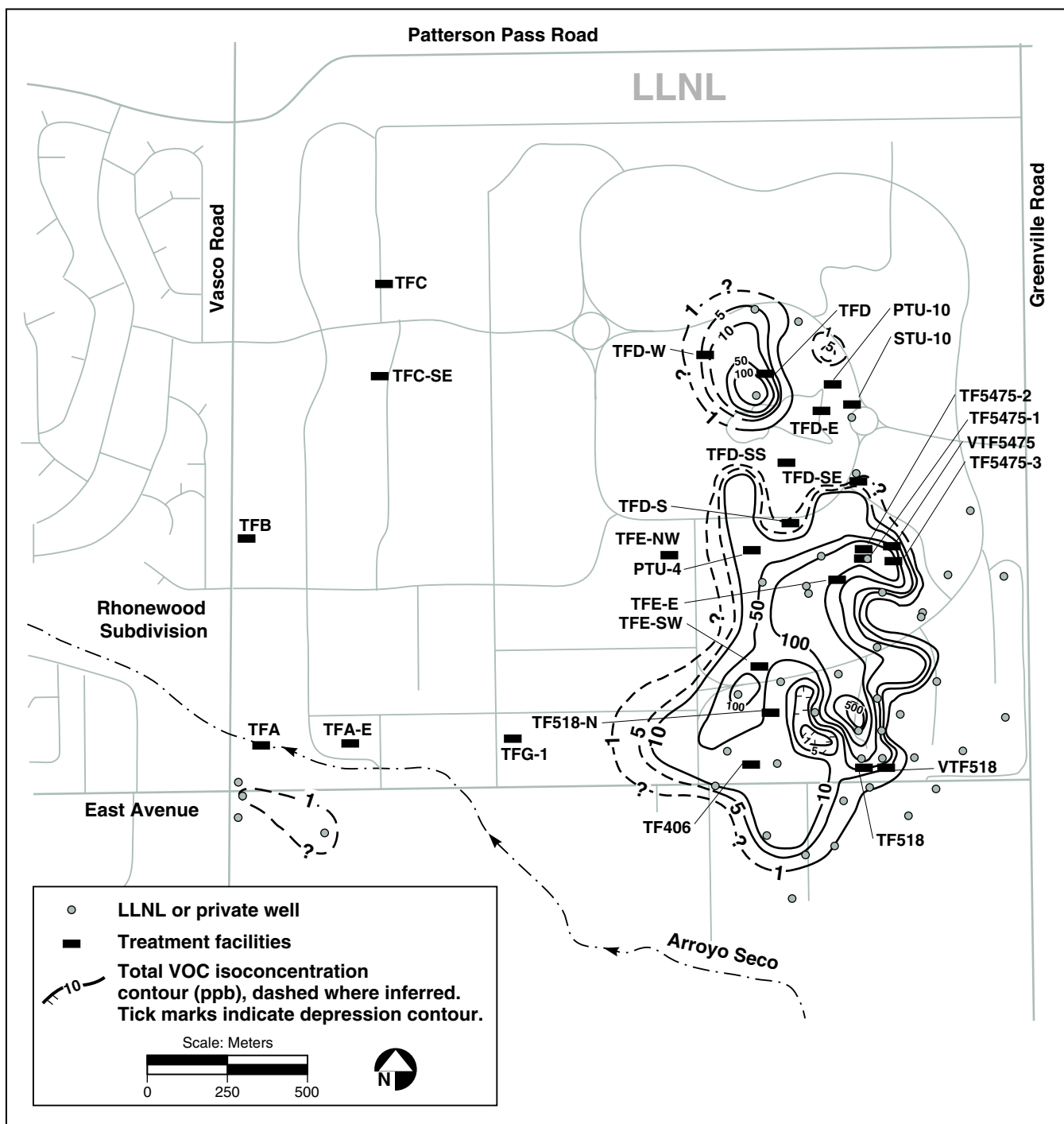


Figure 8-8. Isoconcentration contour map of total VOCs within HSU 5, 2001

Table 8-3. Wells installed in 2001

Treatment facility area	Hydrostratigraphic unit	Monitoring/extraction well
TFA	HSU 2	W-1701
TFB		None
TFC		W-1704
TFD	HSU 6	W-1703
TFE		None
TF406		W-1705
TFG	HSU 2, 3B, 3B, 5	None
TF518		W-1702
TF5475		None

RWQCB discharge substantive requirements. Treated groundwater from TFB is discharged into the north-flowing drainage ditch parallel to Vasco Road that empties into Arroyo Las Positas to the north.

The six wells at TFB pumped at a combined flow rate of about 223 L/min, and treated about 117 million liters of groundwater containing an estimated 6.9 kg of VOCs in 2001.

TFB was in compliance through 2001, and no new wells were installed at TFB during 2001.

Treatment Facility C

Treatment Facility C (TFC) is located in the north-west quadrant of the Livermore site ([Figure 8-1](#)). Portable Treatment Unit (PTU) location TFC Southeast (TFC-SE) is located near the intersection of Avenue A and Sixth Street in the northwest quadrant of the Livermore site.

TFC and TFC-SE process VOCs in groundwater using air stripping. The effluent air from the stripper is treated with granular activated carbon prior to discharge to the atmosphere. Groundwater is treated for chromium(VI) in an ion-exchange unit during the wet season, December through

March, in order to meet the current RWQCB discharge substantive requirements. Treated groundwater from TFC is discharged into Arroyo Las Positas; from TFC-SE, groundwater is discharged into a north-flowing drainage ditch that empties into Arroyo Las Positas to the north. The TFC effluent chromium(VI) concentration was below the wet season discharge limit of 22 ppb during 2001. TFC and TFC-SE complied with all permits throughout 2001.

Wells in the TFC area pumped at a combined flow rate of about 144 L/min and treated about 75 million liters of groundwater containing an estimated 7.2 kg of VOCs. Since system start up in 1993, the combined TFC area facilities have treated more than 475 million liters of groundwater and removed about 47 kg of VOC mass from the subsurface.

One new well (W-1704) was installed in the TFC area during 2001 ([Table 8-3](#)).

Treatment Facility D

The Treatment Facility D (TFD) area is located in the northeast quadrant of the Livermore site (see [Figure 8-1](#)). During 2001, eight treatment



facilities operated in the TFD area. The TFD area extraction wells hydraulically control VOCs in HSUs 2, 3A, 3B, 4, and 5.

Fixed and portable facilities operating in the TFD area process VOCs in groundwater using air stripping, although the STU uses granular activated carbon. The effluent air from the air strippers is treated with granular activated carbon prior to discharge to the atmosphere. Treated groundwater from TFD and TFD-East (TFD-E) is discharged either into the drainage retention basin (DRB), or into an underground pipeline downstream of the DRB weir, flowing northward to Arroyo Las Positas. Treated groundwater from TFD-West (TFD-W) is discharged into a nearby storm sewer that also empties into Arroyo Las Positas. Treated groundwater from TFD-South (TFD-S) and TFD-Southeast (TFD-SE) is discharged into drainage ditches, each flowing north into the DRB.

Electroosmosis (EO) was tested from September 2000 to February 2001 to evaluate its ability to help remove VOCs from fine-grained sediments in a source area near the Helipad in the TFD area. EO uses a direct current passed between electrodes to induce water flow from the anode (positive electrode) to the cathode (negative electrode). Contaminated groundwater is then extracted from the cathode well(s) and treated.

At the Helipad site, a nine-well array was constructed with three cathode wells in the center and three anode wells on each side. Groundwater was extracted at the cathode wells and treated at PTU10. Results from this test suggest a measurable increase in contaminant influx to the extraction wells when EO operated (McNab et al. 2001).

When not connected to the EO pilot test, PTU10, located northeast of the DRB at the TFD Helipad area, continued to operate by treating groundwater from wells W-1551, W-1552, W-1651, and

W-1654 (all in HSU 3A/3B) in 2001 to expedite VOC mass removal and source area cleanup. In 2001, PTU10 operated at a flow rate of about 5.7 L/min, and treated about 3 million liters of groundwater containing an estimated 3.7 kg VOCs. These data are included in the TFD groundwater volume and VOC mass totals are presented in [Table 8-2](#).

The combined TFD facilities operated at an average flow rate of 526 L/min in 2001. During 2001, these units treated about 276 million liters of groundwater containing an estimated 90.1 kg of VOCs. Distal VOC plumes in the western TFD area should be hydraulically controlled once planned TFC-E and TFFC-Northeast (TFC-NE) treatment facilities are operating; they were scheduled to begin operation in January 2002 and May 2003, respectively, but have been postponed due to budget shortfalls.

All TFD facilities were in compliance through 2001. One well (W-1703) was installed in the TFD area during 2001 ([Table 8-3](#)) and a one-hour drawdown test was conducted on the well (Dibley et al. 2002).

Treatment Facility E

The Treatment Facility E (TFE) area is located in the southeastern quadrant of the Livermore site ([Figure 8-1](#)). In 2000, TFE-East (TFE-E) continued treating groundwater using a PTU. TFE-E is located in the east-central portion of the Livermore site and provides hydraulic containment of some portions of VOC plumes in HSUs 2, 4, and 5. TFE-Northwest (TFE-NW) treats groundwater from extraction wells in HSU 2 and HSU 4 and is located south of the Inner Loop Road, immediately west of Southgate Drive.

TFE-E and TFE-NW treat VOCs using an air stripper. Before the effluent air is vented to the atmosphere, it is treated using granular activated

carbon to remove VOCs. Treated groundwater from TFE-E is discharged into a drainage ditch that flows north into the DRB. Treated groundwater from TFE-NW is discharged into a storm drain that flows north into Arroyo Las Positas.

Two new treatment facilities were added to the TFE area in 2001. Operation of TFE-Southeast (TFE-SE), located south of the DRB and South Outer Loop Road, was delayed with regulatory concurrence until March 19, 2001, due to the Federal Continuing Budget Resolution. TFE-West (TFE-W), located south of South Inner Loop Road and east of Southgate Drive was activated April 30, 2001, four days ahead of the Remedial Action Implementation Plan (RAIP) milestone date. Treated groundwater from TFE-SE is discharged into an underground storm drain that flows west and then north into Arroyo Las Positas. Treated groundwater from TFE-W is discharged into an underground storm drain that flows north into Arroyo Las Positas.

In 2001, wells at TFE pumped at a combined flow rate of about 238 L/min and treated about 125 million liters of groundwater containing an estimated 25.4 kg of VOCs. Since system startup in 1996, the combined TFE facilities have treated more than 435 million liters of groundwater and removed about 121 kg of VOC mass from the subsurface.

All TFE treatment facilities were in compliance in 2001. No new wells were installed in the TFE area during 2001.

Treatment Facility G-1

Treatment Facility G-1 (TFG-1) is located in the south-central portion of the Livermore site ([Figure 8-1](#)) and treats groundwater from one well at Treatment Facility G-1 (TFG-1), located near Avenue B, about 90 m north of East Avenue. Under the current RWQCB discharge substantive

requirements, water from TFG-1 requires treatment for chromium(VI) only during December through March. Treated groundwater from TFG-1 is discharged to a storm drain located about 15 m north of TFG-1, which empties into Arroyo Seco.

Before May 1999, TFG-1 processed groundwater for VOC treatment using an air stripper, and the effluent air was treated using granular activated carbon to remove VOCs before they were vented to the atmosphere. In May 1999, the PTU at TFG-1 was replaced by a granular activated carbon treatment unit (GTU). A year-long treatability study conducted in 1998 and 1999 demonstrated that the granular activated carbon treatment was effective in the efficient removal of VOCs from TFG area groundwater. Groundwater is no longer treated for chromium(VI) because concentrations from March 1997 through November 1999 were consistently below the discharge limit of 22 ppb.

During 2001, TFG-1 operated at an average flow rate of 10.79 L/min, treating 5.7 million liters of groundwater containing an estimated 0.3 kg of VOCs ([Table 8-2](#)). Since system startup in 1996, TFG-1 has treated almost 57 million liters of groundwater and removed about 3 kg of VOC mass from the subsurface.

The TFG-1 treatment facility was in compliance in 2001. No new boreholes or wells were drilled and no hydraulic tests were conducted in the TFG area during 2001.

Treatment Facility 406

TF406 is located in the south-central portion of the Livermore site, east of Southgate Drive near East Avenue ([Figure 8-1](#)). In 2001, TF406 treated groundwater from HSU 5 extraction well W-1310. Pumping was discontinued in September 2000 from HSU 4 extraction wells GSW-445 and W-1309 since concentrations had declined below MCLs for all VOCs of concern, and to reduce the



dewatering of HSU 4 in the southeastern corner of the site. These wells were not pumped in 2001 because TCE concentrations in both wells remained below MCLs.

TF406 uses PTU5 equipped with an air stripper to treat VOCs in groundwater. Granular activated carbon removes VOCs from effluent air prior to discharge to the atmosphere. All treated groundwater is discharged to an underground storm drain that flows north to Arroyo Las Positas. TF406 was in compliance with all permits throughout 2001.

When activated in August 1996, TF406 processed groundwater from extraction wells GSW-445 and W-1114. In 1997, well W-1114 was inadvertently damaged and destroyed by adjacent drilling activities, and new extraction wells W-1309 and W-1310 were installed. TF406 began processing groundwater from wells W-1309 and W-1310 in February 1998. As described above, water is no longer pumped from wells GSW-445 and W-1309.

Passive bioremediation continued in the TF406 area during 2001 to remediate FHCs in HSUs 3A and 3B. Active groundwater extraction and treatment for residual dissolved FHCs at former Treatment Facility F (TFF) was discontinued in 1996 with regulatory agency concurrence (RWQCB 1996).

During 2001, TF406 operated at an average flow rate of 76 L/min, treating more than 38 million liters of groundwater containing an estimated 0.9 kg of VOCs (see [Table 8-2](#)). Since system startup in 1996, TF406 has treated about 42.2 ML of groundwater and removed about 6.7 kg of VOC mass from the subsurface (see [Table 8-1](#)).

A multiple-screen monitor well, W-1705, was installed in the future TF406-Northwest (TF406-NW) area in 2001 ([Table 8-3](#)). Well W-1705 is equipped with a Water FLUTe, an instrumented

membrane system (IMS) that allows collection of depth-specific water level and groundwater chemistry data from multiple HSUs at one location. Well W-1705 is screened in HSUs 2, 3A, 3B, and 5. Data from this well will be used to design TF406-NW.

No hydraulic tests were performed in the TF406 area in 2001, and TF406 was in compliance through 2001.

Groundwater Treatment Facility 518

One groundwater treatment facility, TF518 North (TF518-N), operated in the TF518 area in 2001. TF518-N is located south of South Outer Loop Road, north of Building 411 ([Figure 8-1](#)). TF518-N treats groundwater from HSU 4 extraction well W-1410. Another treatment facility, TF518, ([Figure 8-1](#)) extracted groundwater from wells W-211 and W-112 but was removed in June 2000 after HSU 5 became dewatered in the southeastern portion of the Livermore site. HSU 5 remained dewatered throughout 2001.

TF518-N employs a series of aqueous-phase granular activated carbon canisters to treat VOCs in groundwater. Treated groundwater from TF518-N is discharged into an underground storm drain that flows north and ultimately empties into Arroyo Las Positas.

During 2001, TF518-N operated at an average flow rate of 12 L/min, treating 12 million liters of groundwater containing an estimated 0.7 kg of VOCs. Since system startup in January 2000, TF518-N has processed approximately 32 million liters of groundwater containing an estimated 3.7 kg of VOCs ([Table 8-2](#)).

The extraction wells provide hydraulic control of VOC plumes in HSUs 4 and 5 based on the capture zone analysis shown on the groundwater elevation contour maps and the total VOC isoconcentration maps ([Figure 8-7](#) and

Figure 8-8). The sustained de-watering in HSU 5 impacts hydraulic control by widening the capture areas.

One new well (W-1702) was installed in 2001 (**Table 8-3**). No hydraulic tests were conducted in the TF518 area during 2001.

Vapor Treatment Facility 518

Vapor treatment facility 518 (VTF518) is located north of East Avenue in the southeast portion of the Livermore site (**Figure 8-1**). Soil vapor extracted from the vadose zone is passed through a series of granular activated carbon canisters to remove VOCs, and the effluent air is discharged to the atmosphere. VTF518 was in compliance with its Bay Area Air Quality Management District permit throughout 2001.

VTF518 began operation in September 1995 by treating soil vapor from extraction well SVB-518-201. In 1997, extraction well SVB-518-303 was added to the system. Since 1998, the flow rate from primary extraction well SVB-518-201 has dropped from about $0.82 \text{ m}^3/\text{min}$ to less than $0.05 \text{ m}^3/\text{min}$. The majority of vapor flow during this period was from secondary extraction well SVB-518-303. VTF518 was shut down in August 1999, due to lack of flow from primary extraction well SVB-518-201. Field investigations indicated that the reduced vapor flow was most likely due to a significant increase in moisture in shallow sediments, which severely restricted air flow from the vadose zone. It is suspected that above average rainfall since 1995 resulted in the re-appearance of a perched water-bearing zone that had been observed in the 1980s.

Soil vapor extraction (SVE) was restarted at about $0.017 \text{ m}^3/\text{min}$ in July 2000 using existing well SVB-518-204. The vacuum produced by VTF518 caused an upwelling of the perched water which contained up to 80 parts per million (ppm) VOCs.

The perched water was extracted from vapor extraction wells SVB-518-204 and SVB-518-303 on a periodic basis during 2001 to expedite mass removal and to attempt to remove the excess moisture. This water was collected in a tank and transported to TFD for treatment.

From January through May 2001, VTF518 operated at an average flow rate of $0.006 \text{ m}^3/\text{min}$, treating about 2912 m^3 of vapor containing an estimated 2.6 kg of VOCs (**Table 8-2**). In addition, approximately 1420 liters of water, containing about 0.02 kg of VOCs, was extracted from the two vapor extraction wells at VTF518 in 2001. Since system start up in 1995, VTF518 has treated approximately 420 m^3 of vapor and removed about 153 kg of VOC mass from the subsurface (**Table 8-2**).

In November 2001, a new IMS was installed in borehole B-1616, now referred to as IMS-518-1616. The IMS is used to monitor soil moisture and vapor pressures and collect soil vapor samples at various depths. Since 1995, two other IMS sampling/monitor wells, SEA-518-301 and SEA-518-304, have been used for similar vadose zone monitoring.

Data collected in November and December 2001 from IMS-518-1616 indicate that recharge from rainfall occurs much more rapidly than expected. Moisture responses were seen within an hour at a depth of 2.4 m, and up to depths of 12 m within a few hours of rainfall events. Potential explanations for this rapid infiltration are currently being evaluated.

Treatment Facility 5475

Three groundwater treatment facilities operated in 2001 in the Trailer 5475 (T5475) area, located in the east-central portion of the Livermore site (**Figure 8-1**). TF5475-1, activated in September 1998, treats groundwater by in situ catalytic



reductive dehalogenation (CRD) from HSU 3A extraction well W-1302. TF5475-2 (STU5), activated in March 1999, is located west of T5475 and treats groundwater from HSU 2 well W-1415. TF5475-3, activated in September 2000, is located west of T5475 and treats groundwater from two HSU 3A extraction wells, W-1606 and W-1608.

Phase 3 of CRD treatment at T5475, completed nine days ahead of the September 28, 2001, RAIP milestone date, added HSU 5 well W-1610 to TF5475-3.

TF5475-1 uses a down-hole CRD unit (CRD-1) to treat VOCs in groundwater. This technology treats VOCs in groundwater while keeping the groundwater containing tritium in the T5475 area in the subsurface.

CRD technology is based on the reaction of dissolved hydrogen on a palladium catalyst. When in contact with VOC-bearing groundwater, the VOCs are reduced to ethane, methane, or ethene, and free chloride ions. Because of the relatively rapid CRD reaction rates, treatment takes place during one pass through the unit.

CRD-1 operates in extraction well W-1302, a dual-screened well where groundwater containing VOCs and tritium is extracted from the lower screened interval for VOC treatment and is reinjected into the same HSU, via the upper screened interval, after treatment. CRD-1's destruction efficiency ranged from 95.0 to 98.1% in 2001.

TF5475-2 employs STU5 that uses a direct current (DC)-powered pump to extract groundwater through a series of aqueous-phase granular activated carbon canisters for treatment. Since tritium is not a contaminant of concern at TF5475-2, treated groundwater from TF5475-2 is discharged

into an underground storm drain that flows north into Arroyo Las Positas via the DRB. TF5475-2 complied with all permit requirements throughout 2001.

TF5475-3 uses CRD-2 to treat VOCs in groundwater. It is similar in design to CRD-1 except that it is an above-ground treatment unit rather than deployed in a well.

TF5475-3 was designed as a closed-loop system to prevent tritium in HSU 3A from being released above ground. Following activation in 2000, groundwater was extracted from wells W-1606 and W-1608, processed in CRD-2, and then returned to the subsurface using reinjection wells W-1605 and W-1607. TF5475-3 was shut down in May of 2001 to prepare for Phase 3 of TF5475 CRD.

Phase 3 of CRD treatment at facility TF5475-3 uses the CRD-2 treatment unit to treat groundwater pumped from HSU 5 extraction well W-1610 in a closed-loop system. The treated water is then re-injected into HSU 5 well W-1609. The CRD-2 destruction ranged from 93.4 to 99.3% in 2001. HSU 3 extraction well W-1606 is currently inactive because it cannot sustain flow due to de-watering of HSU 3A in the T5475 area. TF5475-3 resumed operation on September 19, 2001.

During 2001, groundwater tritium activities in all T5475 area wells remained below the MCL and continued to decrease by natural decay. VOC concentrations in T5475 area wells were stable or decreasing in 2001.

During 2001, the TF5475 area facilities operated at an average flow rate of 0.72 L/min to treat about 0.4 million liters of groundwater containing an estimated 1.1 kg of VOCs. Since system start up in 1998, the combined TF5475 facilities have

treated about 1.6 million liters of groundwater and removed about 4.2 kg of VOC mass from the subsurface ([Table 8-2](#)).

No new boreholes or wells were drilled and no hydraulic tests were conducted in the T5475 area during 2001.

Vapor Treatment Facility 5475

VTF5475 is located north of TF5475-3 in the east-central portion of the Livermore site, and treats soil vapor from vadose zone well SVI-ETS-504 ([Figure 8-1](#)). VTF5475 began operation in January 1999.

Soil vapor is extracted from the vadose zone and treated at VTF5475 using granular activated carbon. Due to elevated tritium concentrations in the vadose zone, VTF5475 is a closed-loop system to prevent aboveground tritium releases. The vapor stream is heated to reduce the humidity of the tritiated vapor prior to entering the granular activated carbon. This minimizes the absorption of tritium containing water on the granular activated carbon.

Following removal of VOCs from the air-stream, tritiated vapor is re-injected into the subsurface at soil vapor inlet well SVI-ETS-505. Tritium absorbed by the granular activated carbon during VOC treatment is handled as mixed waste. Because no effluent vapor from VTF5475 is released to the atmosphere, the Bay Area Air Quality Management District has granted the facility an exemption from air discharge requirements.

During 2001, VTF5475 operated at an average flow rate of $0.461 \text{ m}^3/\text{min}$ and treated over $241,000 \text{ m}^3$ of vapor containing an estimated 70.2 kg of VOCs. Since system start up in 1999, VTF5475 has treated about $516,000 \text{ m}^3$ of vapor containing an estimated 268 kg of VOCs ([Table 8-2](#)).

Two IMS sampling/monitor wells, SEA-ETS-506 and SEA-ETS-507, continued to monitor vadose zone remediation in the VTF5475 area. The IMS system is used to collect vapor pressure, soil temperature, soil moisture, and soil vapor concentration data from various discrete depths.

Groundwater Flow and Transport Modeling

Groundwater flow and contaminant transport models are used at the Livermore site to optimize remediation system design and operation, to support ongoing subsurface characterization activities, and to improve our ability to forecast, monitor, and interpret the progress of the groundwater remediation program. In 2001, LLNL continued to improve the three-dimensional (3-D) groundwater models for the Livermore site, and began developing new models to extend our evaluation capabilities to include deeper HSUs. Continued use of the existing models and development of new models in 2001 are described below.

HSU 1B /2 Model

In 2001, DOE/LLNL continued to use the 3-D groundwater flow and transport model of HSUs 1B and 2 to evaluate perchloroethylene (PCE) and trichloroethylene (TCE) transport throughout the Livermore site. The model was used to optimize well extraction rates, evaluate potential capture zones of proposed extraction wells, and evaluate plume migration and hydraulic interference patterns under increased pumping conditions. Prior to drilling, the proposed location of extraction well W-1701 was evaluated using the model to help ensure that the well would capture the leading edge of the PCE plume along Arroyo Seco. The long-term hydraulic test conducted in this well showed that model predictions were representative and that well W-1701 fully captures the PCE plume. The model was also used to evaluate the role of the Recharge Basin on the overall remediation of HSUs



1B and 2. This model was revised to include recent well pumping histories, changing boundary conditions, and refined flow and transport parameters to improve simulation results.

Deeper HSU Models

In 2001, four new two-dimensional (2-D) models were developed for deeper HSUs 3A, 3B, 4, and 5. The primary purpose of the individual 2-D models is to understand the flow and transport characteristics of each HSU separately before incorporating them into a larger 3-D model for the entire site. The 2-D models proved very useful in identifying the boundary conditions of these HSUs in terms of recharge and discharge locations, as well as areas of vertical communication. To accurately simulate the impact of source areas in these HSUs, distributed hydraulic conductivity fields were used. The hydraulic conductivity fields were generated using inverse modeling techniques utilizing groundwater elevation data. Preliminary calibration results indicate a general correlation between simulated and measured TCE distributions. Due to the hydrogeologic complexity of the deeper HSUs, some differences in TCE distribution are observed, mostly in the source areas, and LLNL is in the process of resolving discrepancies between the simulated and measured data.

Further refinement and improved calibration to minimize the differences will enable production level use of these models to support remediation decisions.

Electroosmosis Modeling

DOE/LLNL continued to develop a mathematical model to simulate flow and transport that couples groundwater and electroosmosis flow processes. The model is intended to aid in evaluating the field data from the electroosmotic remediation pilot test site in the Helipad area to optimize extraction and injection rates. For further results of this study, see *Field Measurements of Electro-osmotic Transport of*

Ground Water Contaminants in a Lithologically Heterogeneous Alluvial-Fan Setting (McNab et al. 2001).

Environmental Impact

In 2001, the decrease in size and concentration observed in the Livermore site VOC plumes is consistent with the 142 kg of VOC removed by the groundwater extraction wells during 2001. Most of the observed trends in VOC concentrations are attributed to active groundwater extraction and remediation. Notable results of VOC analyses of groundwater received from January 2001 through December 2001 are discussed below.

Concentrations on the western margin of the site either declined or remained unchanged during 2001, indicating continued effective hydraulic control of the western site boundary plumes in the TFA, TFB, and TFC areas. The size of the off-site TFA HSU 1B and 2 VOC plumes remained largely unchanged in 2001, although the concentrations have declined. However, all off-site TFA HSU 3A wells are now below MCLs for all VOCs of concern. In the TFB area, significant concentration reductions were observed in both HSUs 1B and 2. Total VOC concentrations declined below 50 ppb in all monitor wells in the TFB area in 2001. TCE concentrations in HSU 1B well W-269 declined from 20 ppb in 2000 to 10 ppb in 2001, and TCE concentrations in HSU 2 well W-308 declined from 26 ppb in 2000 to 2 ppb. In the TFC area, HSU 1B concentrations remained essentially unchanged.

In the central and eastern parts of the TFD area, HSU 2 VOC concentrations continued to decline in response to pumping the TFD extraction wells. TCE concentrations in HSU 2 extraction well W-906 decreased from 750 ppb in 1995 to 37 ppb in October 2001, and TCE in nearby monitor well W-355 decreased from 3100 ppb in April 1992 to

37 ppb in November 2001. In the northern TFD area, Freon 11 concentrations have declined below the 150 ppb MCL in all HSU 2 monitor wells except well W-423, where the Freon 11 concentration in July 2001 was 420 ppb.

VOC concentrations in HSU 3A TFD area wells also continued to decline in 2001. TCE in extraction well W-1550 decreased from 4,000 ppb in October 1999 to 870 ppb in November 2001. TCE in extraction well W-1552 declined from 9900 ppb in September 1999 to 1500 ppb in October 2001.

In the southern TFD and northern TFE areas, VOC concentrations in HSU 4 continue to show significant decreases due to pumping at HSU 4 extraction wells W-1418 and W-1503. TCE in well W-1418 declined from 750 ppb in 1998 to 85 ppb in November 2001. TCE in well W-1503 declined from 2100 ppb in 1999 to 290 ppb in October 2001.

Westward migration of the HSU 2 VOC plume was observed along the western margin of the TFE area in 2001. TCE in piezometer SIP-331-001 increased from below 0.5 ppb in July 1999 to 20 ppb in March 2001. Hydraulic containment of the western TFE HSU 2 VOC plume was established in April 2001 when TFE-W was activated and groundwater extraction began at HSU 2 extraction well W-305. We anticipate that concentrations should begin to stabilize then decline over the next several years in response to pumping well W-305.

In the TFE-E area, HSU 2 VOC concentrations continued to decline in response to groundwater extraction. TCE in HSU 2 extraction well W-1109 decreased from 1744 ppb in January 1998 to 250 ppb in October 2001. In nearby HSU 2

monitor well W-257, TCE concentrations decreased from a maximum of 6400 ppb in 1988 to 130 ppb in July 2001.

In the TF5475 area, significant VOC concentration decreases continued in 2001. TCE in piezometer SIP-ETS-204 declined from a maximum of 21,000 ppb in November 1997 to 110 ppb in May 2001. TCE in monitor well W-1225 declined from 2900 ppb in March 1997 to 70 ppb in September 2001. However, TCE in monitor well W-1117 increased from 43 ppb in November 1995 to 1600 ppb in November 2001.

In the TF518 and TF406 areas, the off-site HSU 5 VOC concentrations continued to decrease in response to pumping the TF406 extraction wells. TF518 was dismantled and removed after HSU-5 became de-watered in the southeastern portion of the Livermore site. TCE, in off-site monitor well W-219, declined from 100 ppb in October 1997 to 1.4 ppb in October 2001. TCE, in another off-site monitor well, W-225, declined from over 2100 ppb in 1987 to 2.5 ppb in October 2001.

In the TFG area, VOC concentrations in HSU 2 wells continued to decline in response to pumping HSU 2 extraction well W-1111. TCE is the only VOC of concern that is not below its MCL in all HSU 2 wells. TCE in well W-1111 declined from 54 ppb in March 1996 to 5.1 ppb in November 2001. TCE in nearby monitor well W-464 declined from 110 ppb in March 1992 to 1.2 ppb in November 2001. With continued groundwater extraction at well W-1111, we anticipate that TCE should fall below the 5 ppb MCL in all HSU 2 wells during 2002.

During 2001, tritium groundwater activities in all wells remained below the MCL and continued to decrease in activity due to natural decay in the T5475 area.



Site 300 CERCLA Project

Environmental investigations and cleanup activities at Site 300 began in 1981. Site 300 became a CERCLA/Superfund site in 1991, when it was placed on the National Priorities List (NPL). The CERCLA environmental restoration operable units (OUs) are shown in [Figure 8-9](#). All contaminant release sites have been assigned to one of eight OUs based on the nature and extent of contamination, and topographic and hydrologic considerations. The major contaminants of concern are listed in [Table 8-4](#).

Geology of Site 300

Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. Site 300 stratigraphy is shown in [Figure 8-10](#). Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—alluvium and semilithified sediments, mainly of continental origin.
- Early to late Tertiary (5–65 million years ago)—shallow marine and continental sedimentary and volcanoclastic rocks.
- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimentary rocks and ophiolites) and Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks).

Distinctive blue-gray to brown weathering volcanoclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within

Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath Site 300.

The Neroly Formation is the principal hydrologic unit within Site 300 and has been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, [Webster-Scholten 1994]). The complete section of the Neroly Formation is about 150 m thick beneath Site 300.

The floodplain of Corral Hollow Creek lies along the southern boundary of Site 300 and borders portions of the General Services Area (GSA), the High Explosives Process Area, and the area of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble and boulder-bearing terrace gravel derived from sources to the south, with lenses and local cappings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, locally influence groundwater flow within the site and have therefore been studied in great detail as part of the CERCLA investigations.

Hydrogeology of Site 300

Site 300 is semiarid, with an average annual rainfall of 27 cm. The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock consists of interbedded conglomerates, sandstones, siltstones, and claystones (see [Figure 8-10](#)).

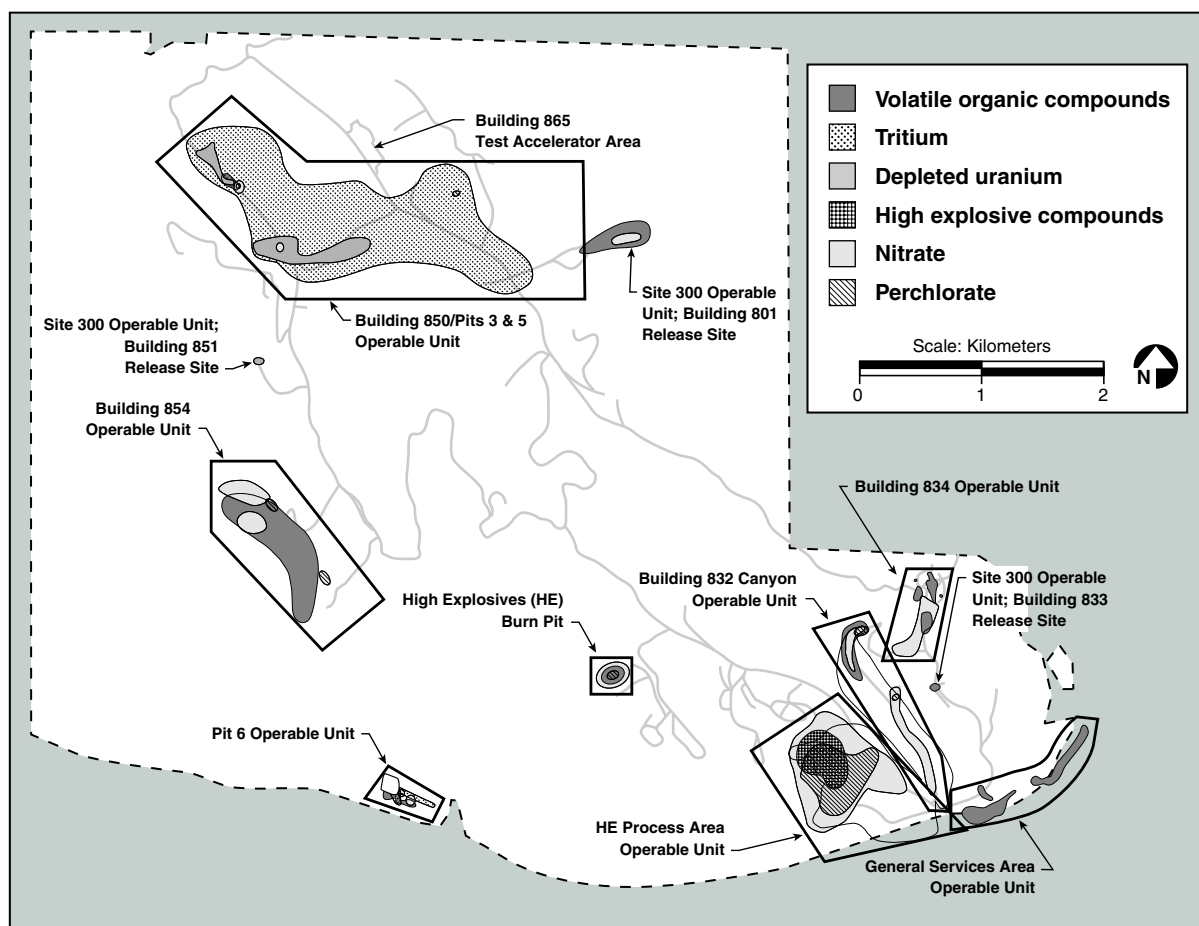


Figure 8-9. Environmental restoration operable units at Site 300

Groundwater primarily occurs in the Neroly Formation upper and lower blue sandstone units ($Tnbs_2$ and $Tnbs_1$) and in the underlying Cierbo Formation ($Tmss$). Saturated conditions also exist in two units that occur at the base of the Neroly Formation in the Building 854 and Pits 3 and 5 areas, respectively ($Tnsc_0$ and $Tnbs_0$). Groundwater can also be present in permeable Quaternary alluvium valley fill (Qal) during the winter rainy season.

Some groundwater is present as perched water-bearing zones beneath hilltops. The perched water-bearing zones primarily occur in the unconsolidated sediments of the Miocene-age nonmarine

unit (Tps) in the Building 833 and 834 areas and in the Explosives Process Area. An extensive perched water-bearing zone also occurs in $Tnbs_1$ sandstones in the northwestern portion of the East and West Firing Area. Fine-grained siltstone and claystone interbeds in $Tnbs_1$ and $Tmss$ act as aquitards, confining layers, or perching horizons. Portions of the bedrock section at Site 300 are abundantly fractured, and thus much of the groundwater flow occurs in fractures as well as in pores. Bedrock-hosted groundwater is typically present under confined conditions in the southern half of the site but is often unconfined elsewhere. [Figure 8-11](#) is a map of the potentiometric surface for the first

**Table 8-4. Major contaminants of concern found in soil, rock, and groundwater at Site 300**

Operable Unit (OU)	Contaminant of concern ^(a)
General Services Area (GSA) (OU1)	VOCs (primarily TCE)
Building 834 Complex (OU2)	VOCs (primarily TCE), Organosilicate oil, Nitrate
High Explosives Process Area (OU4)	VOCs (primarily TCE), HE (primarily HMX), Nitrate, Perchlorate
Building 850/Pits 3 & 5 (OU5)	Tritium, Depleted uranium, VOCs (primarily TCE), Nitrate, Perchlorate
Building 854 (OU6)	VOCs (primarily TCE), Nitrate, Perchlorate
Pit 6 (OU3)	VOCs (primarily TCE), Tritium, Nitrate, Perchlorate
Building 832 Canyon (OU7)	VOCs (primarily TCE), Nitrate, Perchlorate
Site 300 (OU8)	VOCs (primarily TCE and Freon 113), Nitrate, Perchlorate, Depleted uranium

^a See Acronyms and Abbreviations for list of acronyms

continuous water-bearing zone at Site 300, which principally occurs in the Neroly lower blue sandstone aquifer (Tnbs₁).

Recharge occurs where saturated alluvial valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out. Local recharge occurs on hilltops, creating the perched water-bearing zones in the Building 832, 834, 854, and 829/HE Burn Pit areas. Low rainfall, high evapotranspiration rates, steep topography, and intervening aquitards generally preclude direct vertical recharge to the deeper bedrock aquifers.

Groundwater flow in the bedrock follows the inclination, or dip, of the layers. The tectonic forces that uplifted the Altamont Hills faulted, gently folded, and tilted the once-horizontal sedimentary strata. A major structure, the east-west trending Patterson anticline, occupies a central location within the site. North of the anticline, bedrock generally dips east-northeast. South of the anticline, bedrock dips south-southeast.

The Cierbo Formation (Tmss) is saturated beneath Doall Ravine, the Building 851 and 854 areas, and the southern part of the East Firing Area. The Tmss unit is unsaturated or does not otherwise yield water to wells in other parts of the East and West Firing Areas. The thickness of the Cierbo Formation is not well known because most boreholes are not deep enough to completely penetrate this formation. Some of the deeper wells in the GSA penetrate the uppermost Tmss. The continuity of saturation in the Tmss between the northwest and southeast areas of Site 300 is undetermined. Groundwater in the Tmss occurs under unconfined to artesian conditions.

The Tps unit is the youngest bedrock unit identified at Site 300 and is generally present only on hilltops. Where present, groundwater is typically perched, discontinuous, and ephemeral. The exception to this condition exists in the Explosives Process Area, where the extent of saturation in Tps sediments is significant. Groundwater in the Tps unit is generally unconfined, although water under confined conditions does occur locally.

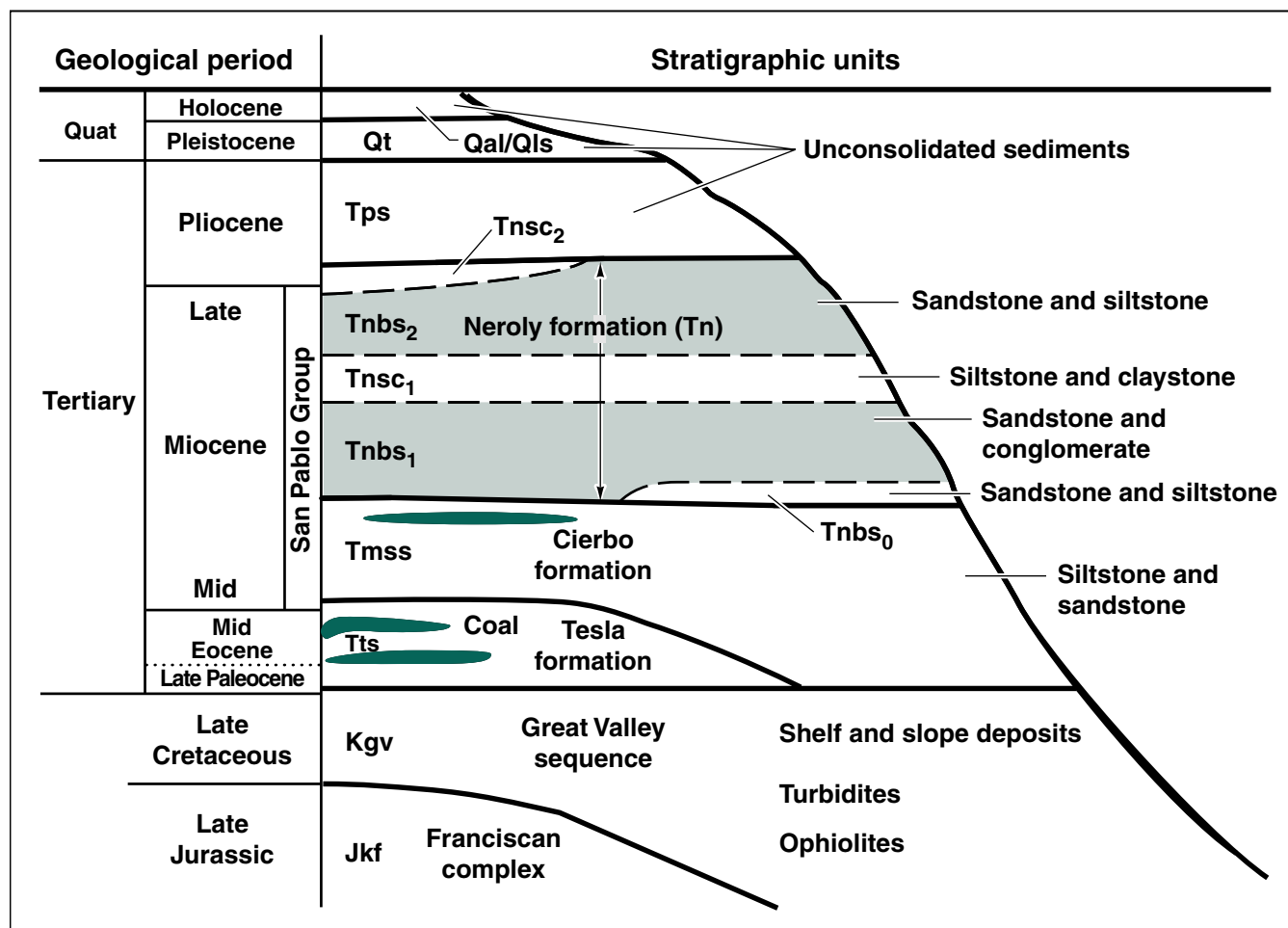


Figure 8-10. Site 300 stratigraphy (Webster-Scholten 1994)

Quaternary alluvium (Qal) is present as valley fill in ravines throughout Site 300 but is perennially saturated only in the Corral Hollow Creek stream channel, in Doall Ravine, and in southern Elk Ravine in the vicinity of Building 812. Qal in the Pits 3 and 5 area is only saturated during rainy seasons and for extended periods of higher than normal rainfall. Saturated Quaternary terrace alluvium deposits (Qt) are present at Pit 6, in the General Services Area (GSA,) and in the Building 832 Canyon area; some of these groundwater occurrences are ephemeral. Small quantities of groundwater are present in some local landslide (Qls) deposits.

All groundwater contaminant plumes at Site 300 occur in Neroly Formation (Tn) rocks, unnamed Pliocene nonmarine sediments (Tps), or unconsolidated Quaternary sediments (Qal, Qls, or Qt) stratigraphic units. The extent of groundwater contamination at Site 300 is shown on [Figure 8-12](#).

Operable Unit Highlights and Activities

Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994). LLNL submitted all required

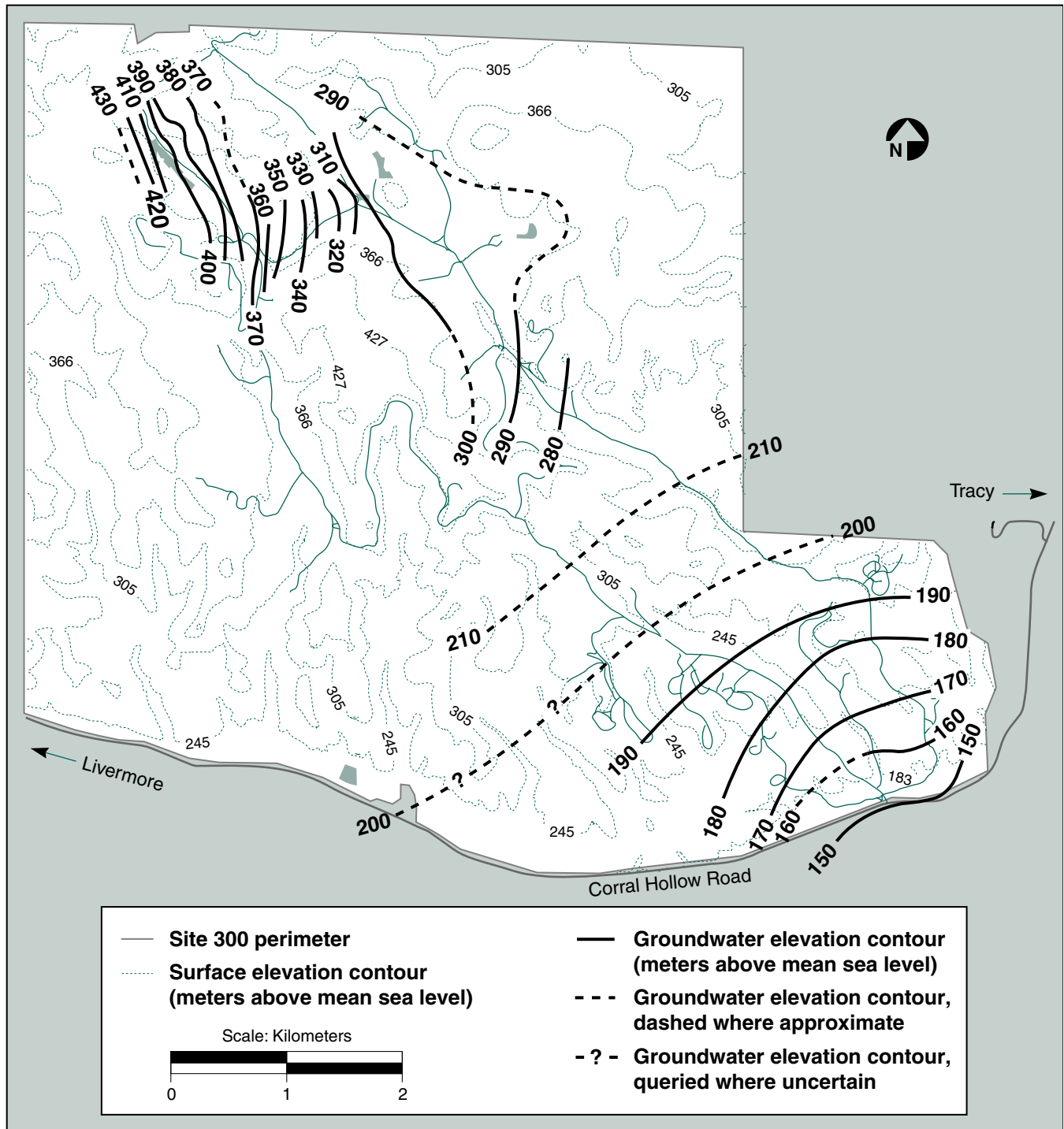


Figure 8-11. Approximate groundwater elevations in the principal continuous water-bearing zone at Site 300

documentation to oversight agencies on time in 2001. The *Draft Final Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300* (U.S. DOE 2001), *Five-Year Review Report for the General Services Area Operable Unit* (Ferry et al. 2001b), *Remedial Design Work Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2001c), *Draft Five-Year Review Report for the Building 834 Operable Unit* (Ferry et al. 2001c), *Draft Final Interim Remedial Design for the Building 834 Operable Unit Treatment Facility* (Gregory et al. 2001), quarterly reports, and other work plans were among the documents submitted.

Background information and a summary of characterization activities for each of the OUs are described in the following sections. Groundwater remediation for Site 300 is discussed in more detail later in this chapter. See Chapter 9 for a discussion of 2001 groundwater monitoring.

General Services Area Operable Unit

In the General Services Area (GSA), past leaks of solvents from storage areas and buried debris have resulted in several plumes of volatile organic compounds (VOCs) in groundwater. There are three major TCE plumes and two treatment facilities located within the GSA OU, which is divided into the central GSA and the eastern GSA.

The VOC groundwater plume in the eastern GSA is present in subsurface stream channel alluvium (Qal) at 3–9 m below the ground surface; the plume, as defined by the 1 µg/L concentration contour, is about 538 m long (**Figure 8-13**). Groundwater in the alluvium flows east and north-east below the Corral Hollow Creek streambed. The maximum 2001 total VOC concentration in groundwater from the eastern GSA wells was 7.3 µg/L. The Qal is hydraulically connected to the Neroly Formation lower blue sandstone (Tnbs1) unit.

Two VOC groundwater plumes in the central GSA are present in terrace alluvium (Qt) and the Neroly Formation upper blue sandstone (Tnbs₂) at a depth of 3–9 m below the surface. These VOC plumes are about 137 m and 396 m long (**Figure 8-14**), respectively. Maximum 2001 total VOC concentrations in alluvial groundwater were 757 µg/L. Deeper groundwater in the bedrock regional aquifer also contained total VOCs at a maximum concentration of 6 µg/L in 2001. This groundwater occurs at depths of 11–56 m below the surface.

Details of current and planned environmental restoration activities at the GSA are summarized in the *Final Remedial Design* (RD) document (Rueth et al. 1998). This document includes the Contingency Plan and Compliance Monitoring Plan for the GSA OU.

By analyzing chemical, hydrogeologic, and hydraulic test data, LLNL determined that the direction of plume migration likely follows a previously unidentified buried stream channel. After 8 years of treatment, by the fall of 1999, the eastern GSA off-site plume (as defined by the 5 µg/L TCE contour line) had been restricted to the Site 300 property. Before the treatment commenced in 1991, the plume had previously extended more than a mile down the Corral Hollow stream channel in the direction of the City of Tracy.

After determining that the eastern GSA VOC plume was restricted to the site, LLNL reconsidered the need for an off-site treatment facility as outlined in the RD. TCE concentrations have decreased to below drinking water standards in groundwater from all off-site wells. Thus, LLNL has determined that an off-site extraction and treatment system is not needed or justified. The regulatory agencies have concurred that the off-site

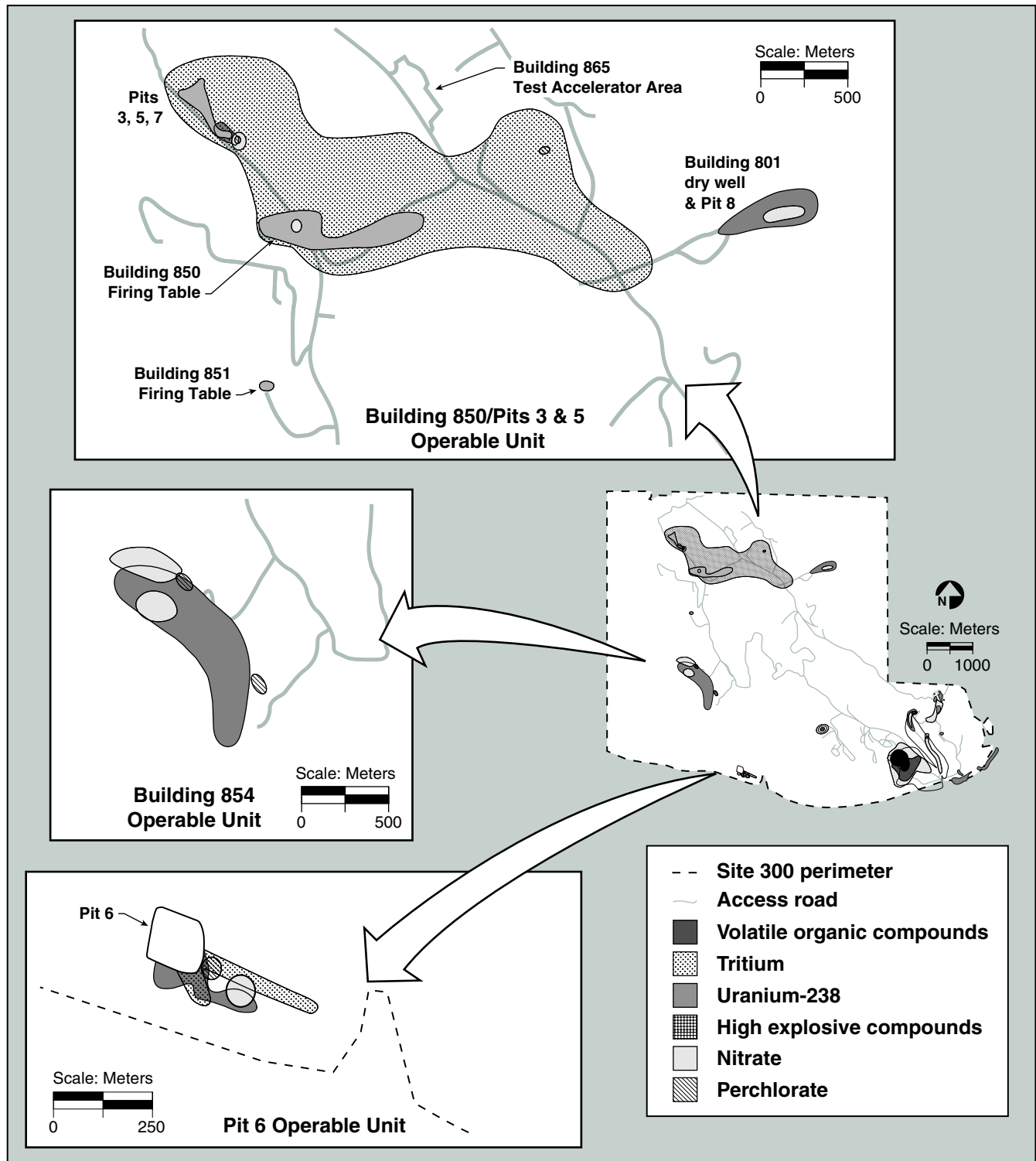
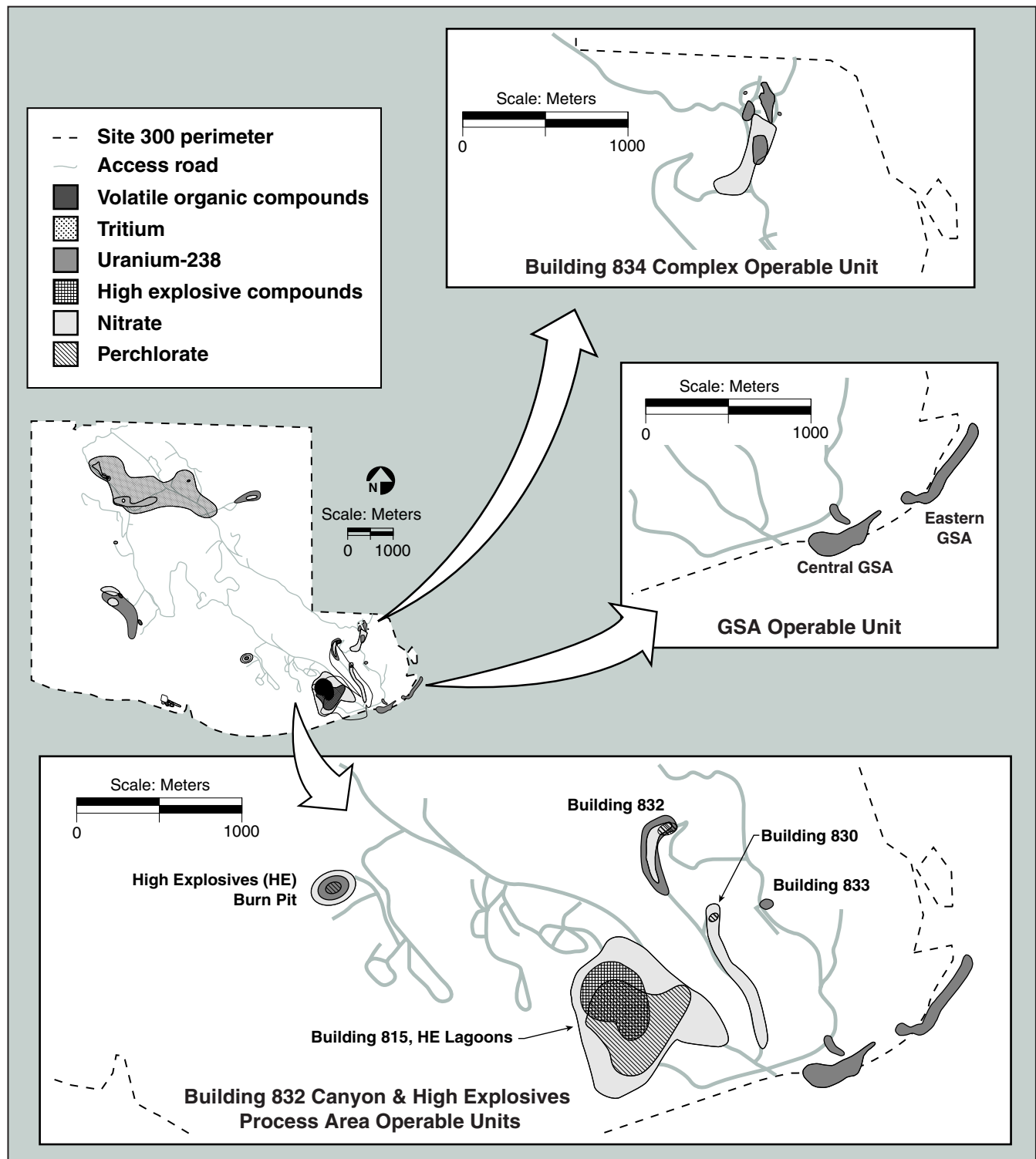


Figure 8-12. Extent of groundwater contamination at Site 300



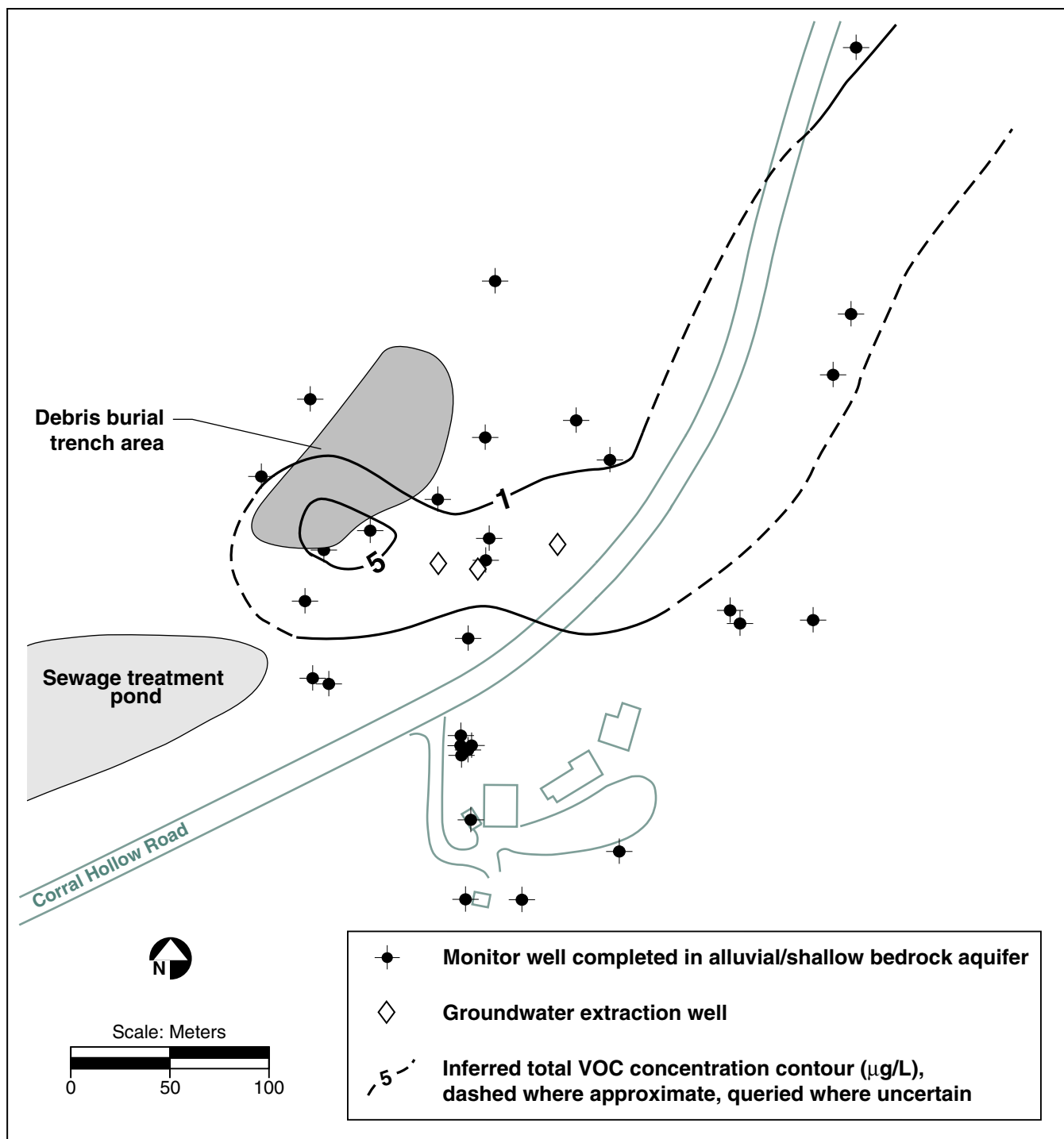


Figure 8-13. Total VOC concentrations in groundwater in the eastern GSA and vicinity (4th quarter, 2001)

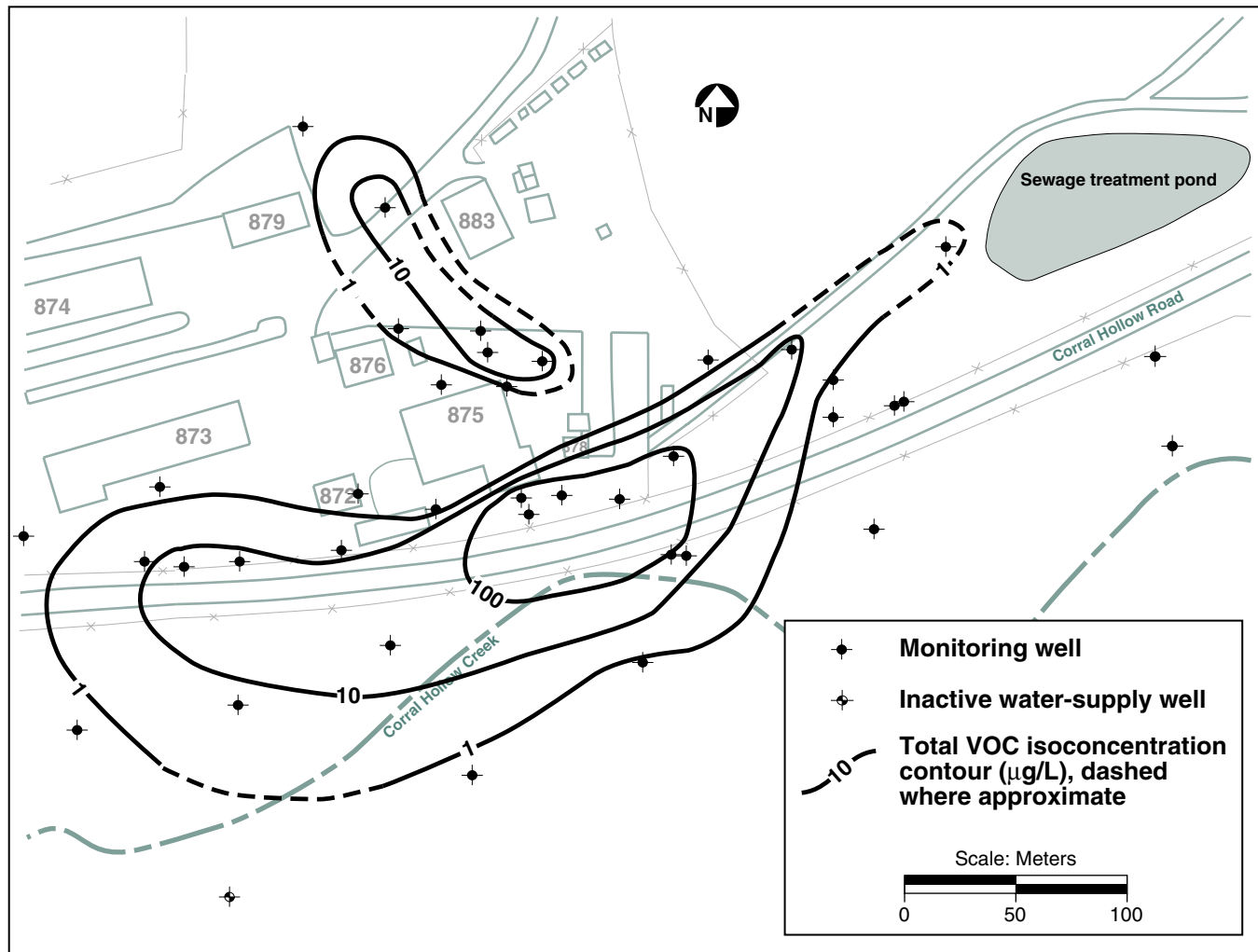


Figure 8-14. Total VOC concentrations in groundwater in the central GSA (4th quarter, 2001). Monitoring wells are completed in the Qt-Tnsc₁ hydrologic unit.

treatment system milestone can be delayed and that the need would be reevaluated during the GSA Five-Year Review.

The milestone to complete the *Draft Final Five-Year Review Report* was met on October 15, 2001. This purpose of this report is to determine whether the current pump-and-treat remedy for the GSA is protective of human health and the environment and to address all issues pertaining to the remediation efforts in progress

Building 834 Operable Unit

Since the late 1950s, the Building 834 complex, consisting of twelve separate buildings, has been used for weapons component testing. TCE was used as the primary heat transfer fluid in experiments involving thermal cycling of weapons components. TCE was pumped between buildings through aboveground pipelines. Occasionally, TCE was mixed with silicone oils, tetrabutyl orthosilicate (TBOS), and tetrakis (2-ethylbutyl) silane (TKEBS) to prevent degradation of pump seals and gaskets. Several large spills of TCE to the ground,



estimated at 550 gallons, and smaller releases of TBOS and TKEBS, resulted in contamination of a shallow perched water-bearing zone beneath the site. Natural biodegradation of the TCE, in the form of anaerobic dehalogenation, has been occurring in discrete zones resulting in the formation of appreciable amounts of cis-1,2-DCE. This intrinsic biodegradation is facilitated by fermentation of TBOS and TKEBS, which yields the hydrogen required for microbial dechlorination of VOCs.

An isolated, discontinuous, perched water-bearing zone occurs in Pliocene non-marine gravels (Tpsg) and occurs at a maximum depth of 9 m below the center of the complex. Within this Tpsg unit exist multiple thin water-bearing layers containing distinctive plumes that may be in hydraulic communication only following periods of heavy rainfall and the resulting higher groundwater elevations. The Tpsg is underlain by a clay perching horizon (Tps) which is nearly saturated. Tpsg and Tps strata crop out on all sides of the hill housing the Building 834 complex and are hydraulically isolated from the underlying regional aquifer by more than 90 m of unsaturated zone. Although the maximum total VOC groundwater concentration within the Tpsg during 2001 was 87,000 µg/L, the highest VOC concentrations in groundwater were found in the Tps perching horizon. This Tps has a very low hydraulic conductivity, but does yield some groundwater. The highest concentration of VOCs in groundwater samples obtained from the Tps during 2001 was 250,000 µg/L, which was predominantly TCE. The groundwater VOC distribution within the Tpsg is presented in **Figure 8-15**. The highest concentration of TBOS/TKEBS in groundwater during 2001 was 180,000 µg/L. High levels of nitrate (maximum 2001 concentration of 280 mg/L) also occur in the groundwater in the Building 834 OU, but the source is uncertain. Effluent from the septic system leach field has possibly contributed to elevated

nitrate concentrations in groundwater. Additional natural and/or anthropogenic nitrate sources may exist.

Groundwater treatment began during the 4th quarter of 1995. Soil vapor extraction and treatment commenced during the 3rd quarter of 1998.

Currently, groundwater and soil vapor extraction and treatment, using air-sparging and granular activated carbon, respectively, are in progress. Aqueous phase granular activated carbon is being tested as a possible replacement of air sparging for VOC removal from groundwater.

During 2001, LLNL submitted to the regulatory agencies, the *Draft Interim Remedial Design Report for the Building 834 Operable Unit Treatment Facility* (Gregory et al. 2002) and the *Draft Five-Year Review Report for the Building 834 Operable Unit* (Ferry et al. 2001a). One paper was presented in 2001 at the 97th Annual Meeting of the Geological Society of America (Madrid et al. 2001).

High Explosives Process Area Operable Unit

The High Explosives Process Area was established in the 1950s to chemically formulate, mechanically press, and machine high explosives (HE) compounds into detonation devices that are tested in explosives experiments in the East and West Firing Areas of Site 300. Process waste water from HE machining operations containing HMX, RDX, nitrate, and possibly perchlorate was discharged to nine former unlined lagoons at concentrations high enough to impact groundwater.

A concrete hardstand on which TCE was stored, located near the former Building 815 steam plant, is considered to be the primary source of TCE groundwater contamination. HMX and RDX are the most frequent and widespread HE compounds detected in soil and groundwater. TCE, nitrate,

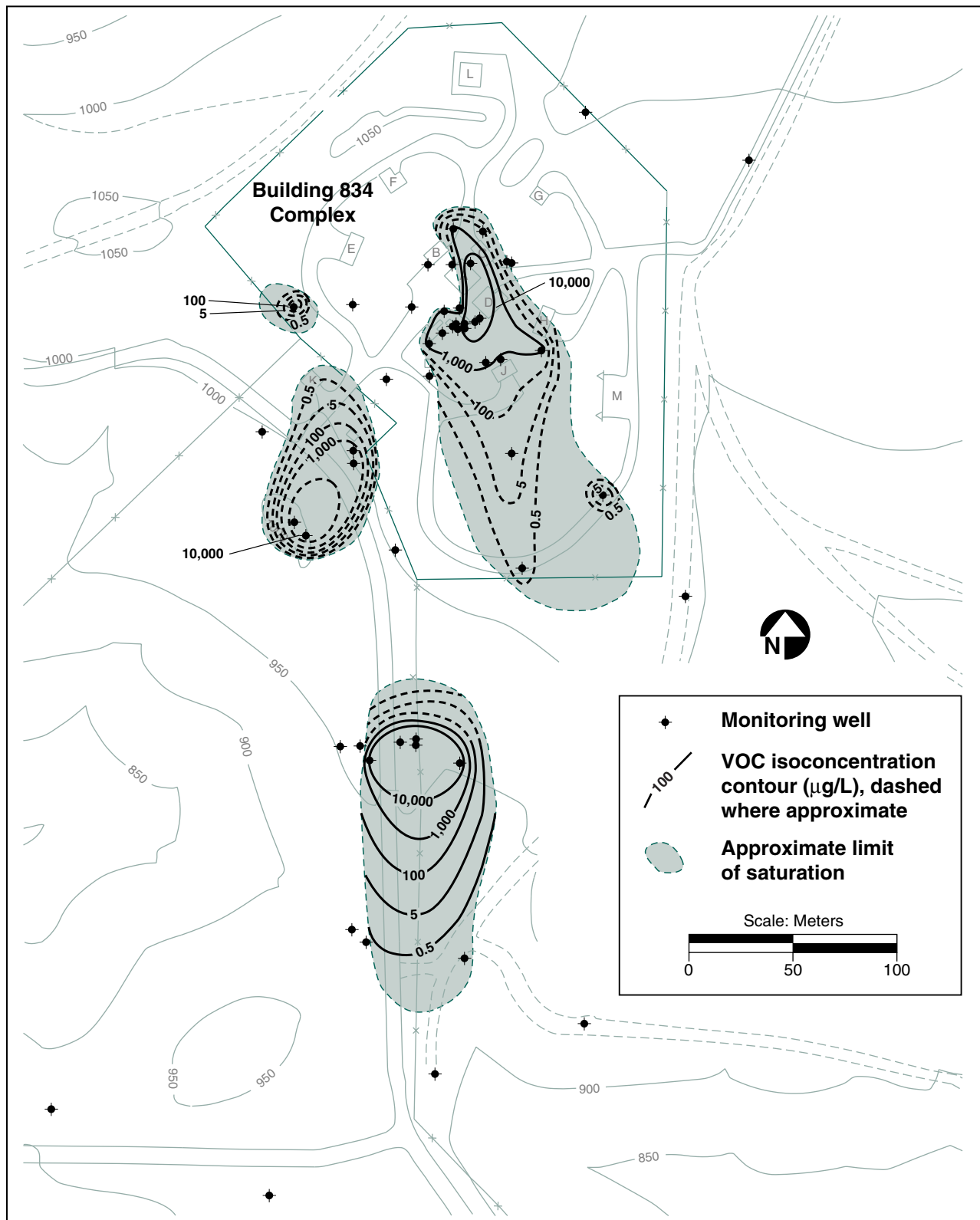


Figure 8-15. Isoconcentration contours for total VOCs in groundwater in the Qt-Tpsg hydrologic unit at the Building 834 complex (4th quarter, 2001)



perchlorate, and RDX occur in groundwater within two separate water-bearing zones. One of the water-bearing zones occurs in the Tps formation and the other occurs in the Tnbs₂ sandstone. Depth to groundwater ranges from 2 to 76 m. The VOC (principally TCE) plume in Tps strata is about 200 m long; the VOC plume in the Tnbs₂ aquifer is about 900 m long (**Figure 8-16**). The RDX plume is about 200 m long and the perchlorate plume is about 600 m long in the Tnbs₂ aquifer. The extent of nitrate above the MCL in the Tnbs₂ aquifer is about 700 m long. In 2001, maximum concentrations of TCE, RDX, nitrate, and perchlorate were 73 µg/L, 140 µg/L, 98 mg/L, and 33 µg/L, respectively.

Building 850/Pits 3 and 5 Operable Unit

Explosives experiments conducted at outdoor firing tables in the Building 850/Pits 3 and 5 area have generated wastes that in the past were disposed at several unlined land-fills. Tritium has been released to groundwater from landfill Pits 3 and 5 and the Building 850 firing table (**Figure 8-17**). Depleted uranium has been released to groundwater from landfill Pits 3, 5, and 7 and the Building 850 firing table. Release of tritium and uranium occurred from water-table rise and lateral flow of upgradient groundwater into the landfills and percolation of rainfall runoff water through the Building 850 firing table to underlying groundwater. The resulting plumes occur in a perched water-bearing zone within Qal alluvium and bedrock at the base of the Neroly Formation in the Tnbs₀. The water-bearing zone occurs at depths of 5–20 m below surface. There are three overlapping plumes of tritium in groundwater.

The maximum 2001 tritium activity was about 11,555 Bq/L (312,000 pCi/L). The total length of the co-mingling tritium plumes was about 3000 m. The perched water-bearing zone is connected to the regional Tnbs₁ aquifer at the Elk Ravine Fault. Maximum 2001 groundwater tritium

activities in this aquifer were about 563 Bq/L (15,200 pCi/L). There are two smaller plumes of depleted uranium (uranium-238), with maximum measured 2001 activities of about 7.4 Bq/L (199 pCi/L) and 0.2 Bq/L (5.4 pCi/L), respectively. The depleted uranium is confined to the perched water-bearing zone; the lengths of the two uranium plumes are about 380 m and 500 m, respectively. Computer modeling of contaminant fate and transport indicates that by the time the tritium and uranium in groundwater could reach the Site 300 boundary, these radionuclides will exist at near-background activities.

A remedial investigation/feasibility study (RI/FS) is in process for the Pits 3 and 5 area. The anticipated remedial technologies to be implemented at the landfill site include source isolation to prevent further release of tritium and uranium to groundwater. These technologies may include an upgradient interceptor trench and surface and shallow subsurface water diversion. LLNL is testing reactive media for possible deployment in a permeable reactive barrier for removal of depleted uranium from Pit 5 and 7 downgradient groundwater.

Although tritium continues to leach into groundwater from vadose zone sources at Building 850, the long-term trend in total groundwater tritium activity in this portion of the tritium plume is one of decreasing activity at approximately the radioactive decay rate of tritium. The extent of the 740 Bq/L (20,000 pCi/L) MCL contour for this portion of the plume is shrinking.

Nitrate and perchlorate in the Building 850/Pits 3 and 5 area occurred at maximum concentrations of 52 mg/L and 5.7 µg/L, respectively, in 2001. Trace amounts of TCE (less than 6.4 µg/L) are also present in groundwater near Pit 5.

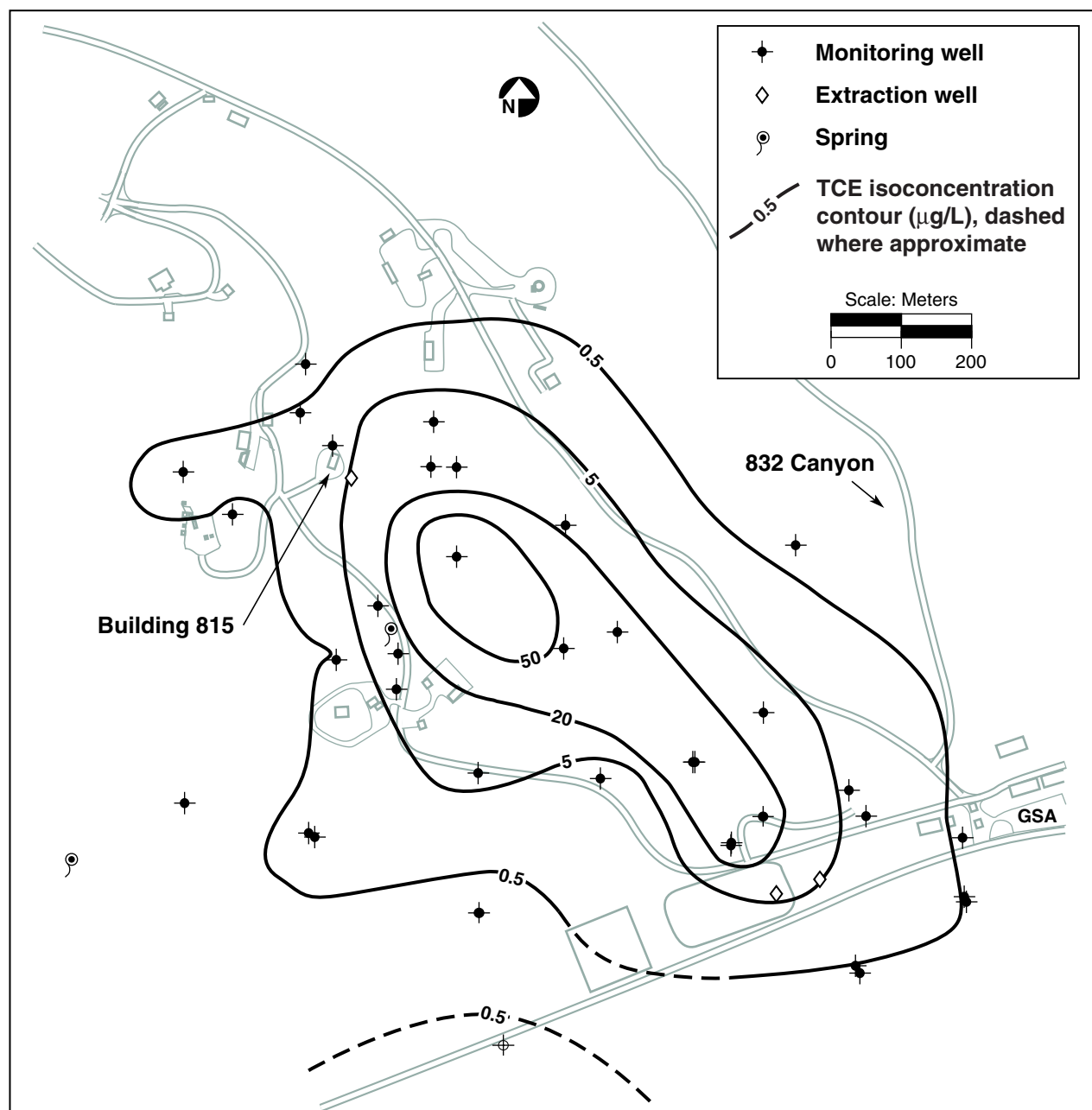


Figure 8-16. Isoconcentration contour map of trichloroethene (TCE) in groundwater in the Tnbs₂ aquifer in the HE Process Area (2nd quarter, 2001)

Building 854 Operable Unit

TCE in groundwater was previously found to arise principally from leaks in the former overhead TCE brine system at Buildings 854E and 854F. TCE,

nitrate, and perchlorate occur in groundwater in the Building 854 area in Neroly Formation Tnbs₁ strata at maximum 2001 concentrations of 290 $\mu\text{g/L}$, 160 mg/L , and 11 $\mu\text{g/L}$, respectively.

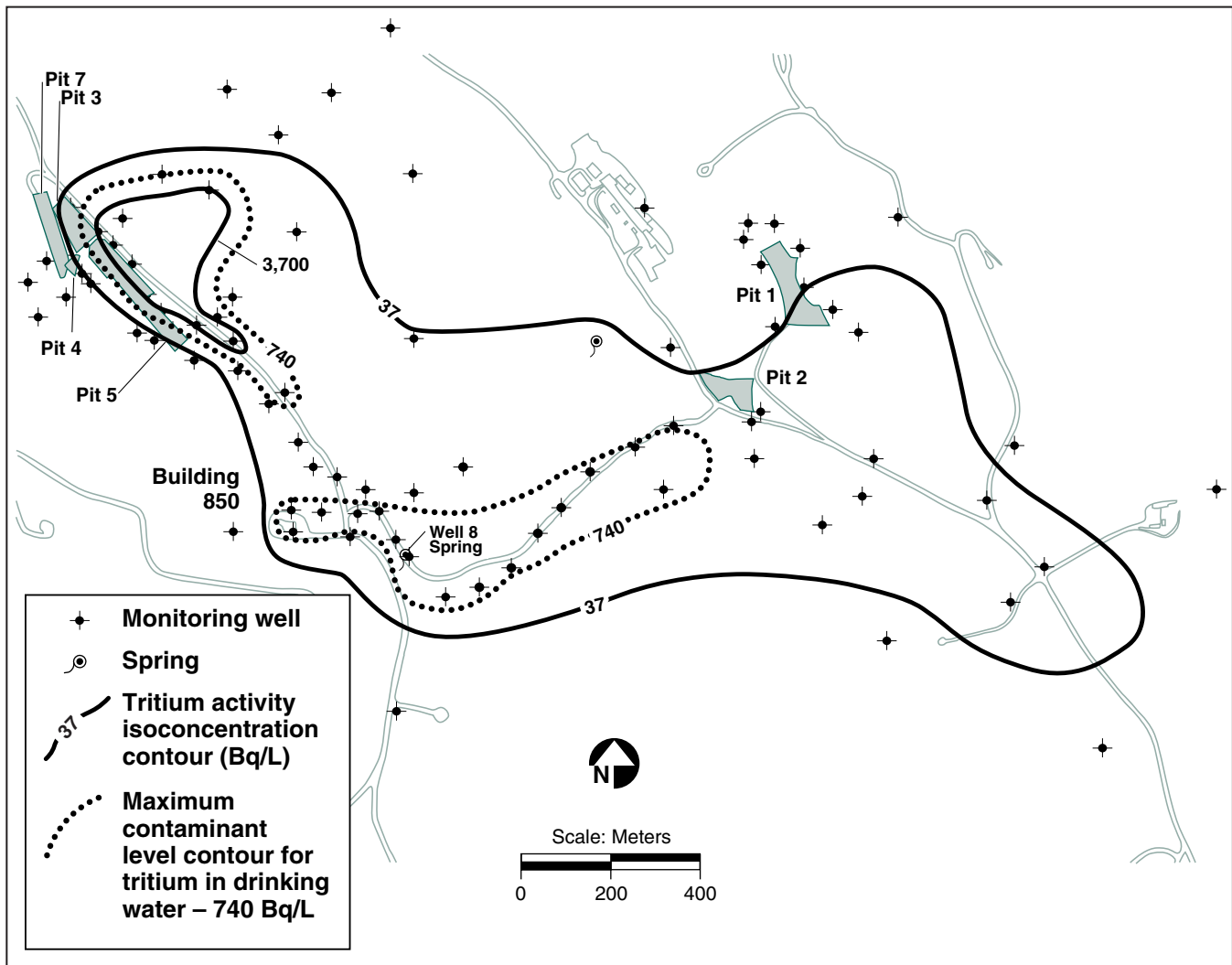


Figure 8-17. Distribution of tritium in groundwater in the first water-bearing zone in the Building 850/Pits 3 and 5 Operable Unit (2nd quarter, 2001)

The affected aquifer occurs at depths of 9–50 m below the surface. The TCE plume is about 1000 m long (Figure 8-18). TCE also occurs in underlying Tnsc₀ strata at maximum concentration 2.8 ppb.

During 2001, LLNL continued to define the extent of TCE in groundwater and the conceptual hydrogeological model. Four new monitor wells were installed along the downgradient and west sides of the groundwater TCE plume.

In 1999, LLNL installed and began operating a solar-powered portable treatment unit at Building 854 to treat extracted groundwater containing VOCs and nitrate. A second treatment unit was installed in 2000. This treatment unit uses activated carbon and a containerized wetlands, a modular, mobile unit that implements phytoremediation technology to treat VOCs, nitrate, and perchlorate.

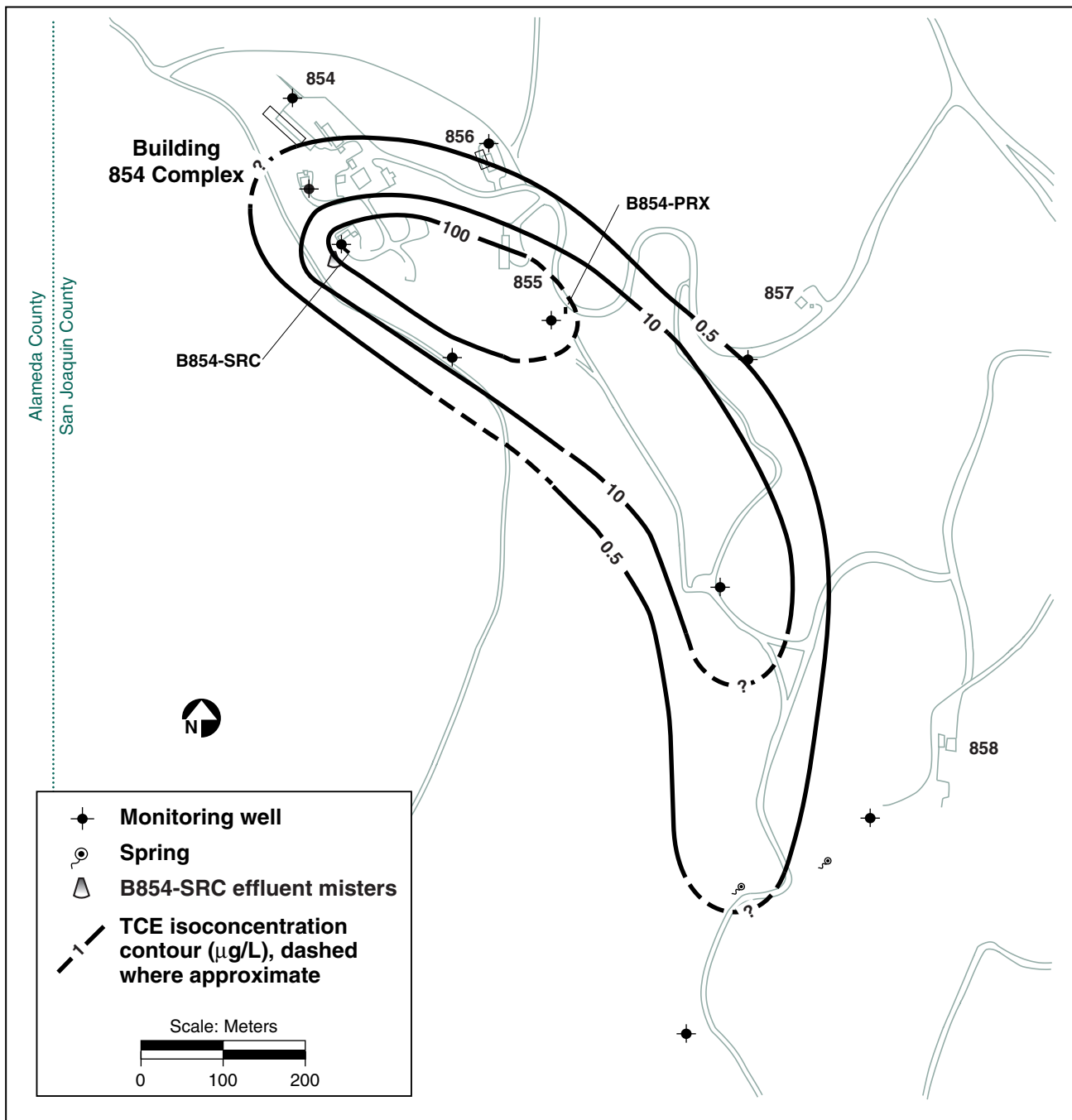


Figure 8-18. Distribution of TCE in groundwater in the Tnbs₁ aquifer in the Building 854 area (4th quarter, 2001)

Pit 6 Operable Unit

A low concentration groundwater TCE plume occurs in a perched water-bearing zone in terrace alluvium (Qt) and in the upper part of underlying Tnbs₁ sandstone (**Figure 8-19**). This perched water-bearing zone occurs at depths of 0–25 m below the surface. The source of the TCE plume,

which is about 200 m long, is likely the southeast portion of the capped Pit 6 landfill. Concentrations of TCE in the plume have declined fivefold since 1992. The 2001 maximum groundwater TCE concentration was 5.4 µg/L, which is similar to the previous two years. Tritium (**Figure 8-19**) at a maximum activity of 77 Bq/L (2080 pCi/L) and

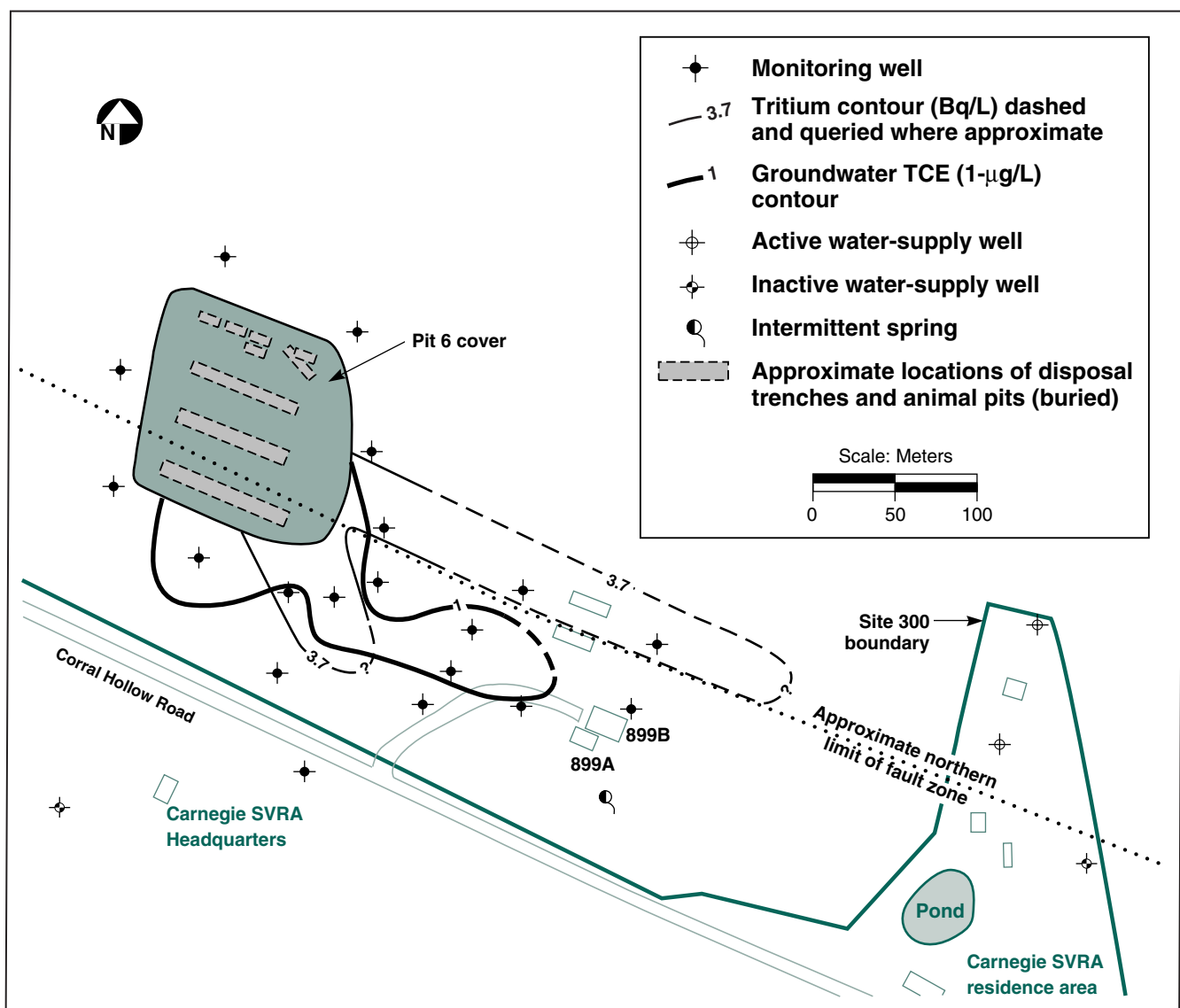


Figure 8-19. Distribution of TCE and tritium in groundwater in the Pit 6 area (4th quarter, 2001)

perchlorate at a maximum concentration of 19 µg/L also occur in the perched water-bearing zone. The lengths of the tritium and perchlorate plumes are 275 and 200 m, respectively. While low in activity, this tritium plume appears to be influenced by heavy pumping from off-site Carnegie State Vehicular Recreation Area water-supply wells, and is being closely monitored. During 1997, a 2.4-acre engineered cap was constructed over the landfill as a CERCLA nontime-critical removal action.

Building 832 Canyon Operable Unit

At the Building 832 Canyon area (Buildings 830 and 832), solvents were released from weapons component test cells. TCE, perchlorate, and nitrate occur in groundwater primarily in Qal alluvium, and in Neroly Formation sandstone units within Tnsc₁ silty-claystone strata at a depth of 15–25 m. Groundwater TCE occurred at a maximum 2001 concentration of 9400 µg/L. The TCE plume emanates from both the Building 830 and 832 areas and is about 1400 m long ([Figure 8-20](#)). Perchlorate has also been detected at a maximum 2001 concentration of 26 µg/L. Nitrate concentrations in groundwater in 2001 reached a maximum of 194 mg/L (ppm). Well drilling conducted over the last three years indicates that the TCE contaminant plume emanating from the Building 832 complex is merging with the TCE in groundwater from the Building 830 area. A groundwater and soil vapor extraction and treatment system has been operating to remove contaminant mass at the Building 832 source area. Groundwater is also extracted and treated to remove VOCs, nitrate and perchlorate, at two remediation systems located downgradient of the Building 830 source area.

Site 300 Operable Unit

The Site 300 OU consists of several small release sites where active remediation is not required, as well as several sites where characterization has yet

to be completed. Sites in the OU include Building 801D dry well and Pit 8 Landfill, Building 833, Building 845 Firing Table and Pit 9 Landfill, Building 851 Firing Table, Building 812 Firing Table, Building 865 (Advanced Testing Accelerator), and Sandia Test Site.

VOCs have been detected in groundwater in the vicinity of the Building 801D dry well; however, concentrations are below drinking water standards (< 5 µg/L). Debris from the Building 801 firing table was buried in the Pit 8 Landfill. No contaminants have been detected in groundwater in the vicinity of the landfill. Groundwater monitoring will continue in this area to monitor the VOC concentrations and to detect any future releases from the landfill.

Contaminant releases, such as spills and leaching from a disposal lagoon adjacent to Building 833, resulted in VOC contamination of the ephemeral perched water-bearing zone. VOC concentrations have decreased over time and the monitoring of groundwater will continue in this area.

Leaching of contaminants from the Building 845 firing table resulted in the contamination of subsurface soil with uranium, tritium, and HMX. Firing table debris from Building 845 was disposed in the Pit 9 Landfill in the late 1950s and early 1960s. No contamination has been detected in groundwater in the vicinity of the landfill or firing table. Groundwater monitoring will continue in this area to detect any future releases of contaminants from soils under the firing table or the landfill.

Explosive experiments at the Building 851 firing table resulted in the release of low concentrations of metals, RDX, tritium, and uranium to soil. Although isotopic ratios indicative of depleted uranium have been found in groundwater samples from three wells, groundwater has not otherwise

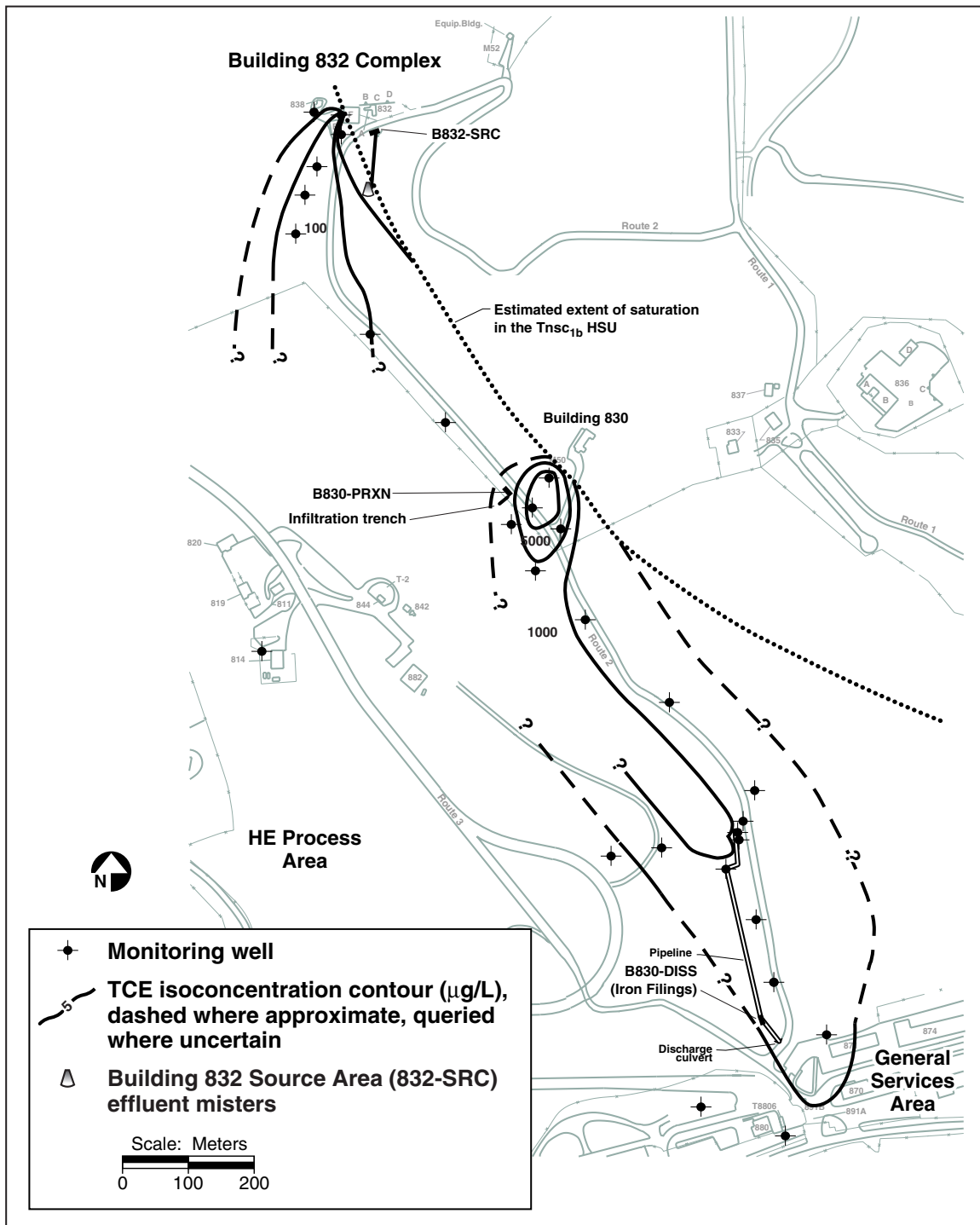


Figure 8-20. Distribution of TCE in groundwater in the Building 832 Canyon (4th quarter, 2001)

been impacted. The maximum 2001 total uranium groundwater activity was 0.015 Bq/L (0.4 pCi/L). Monitoring will continue to evaluate any future impacts to groundwater from soil contaminants.

LLNL continues to evaluate the nature and extent of Freon 113 at Building 865 (the closed Advanced Testing Accelerator). Freon 113 was used as a degreasing agent at the facility. Freon 113 was originally discovered in groundwater samples from wells in the Pit 1 monitoring network, downgradient and southeast of Building 865. Maximum Freon 113 concentrations in groundwater in this area are significantly less than the 1.2 ppm MCL for Freon 113.

There are eight monitor wells at Building 812, a firing table where depleted uranium and thorium were used in explosives experiments. The maximum total calendar year 2001 uranium activity found in groundwater sampled from these wells is 0.42 Bq/L (11.4 pCi/L). Further investigative work is planned.

From 1959 to 1960, Sandia National Laboratories/California, (Sandia/California), operated a small, temporary firing table in the East Firing Area of Site 300. Future characterization work is planned for this area.

Environmental Remediation at Site 300

Dedicated groundwater and soil vapor extraction and treatment facilities operate at the eastern GSA, central GSA, and Building 834 areas. Seven portable treatment facilities also are operating. Thus, in all, 10 treatment facilities that remove and treat VOCs operated throughout 2001. Nineteen wells that extract only groundwater, 7 wells that extract only soil vapor, and 24 wells that extract both groundwater and soil vapor, operated during 2001, treating about 94.7 million L of groundwater. The 24 wells that extract both vapor and

groundwater and the 7 wells that extract only vapor removed 922,000 m³ of vapor. In 2001, the Site 300 treatment facilities removed approximately 36.1 kg of VOCs. Since remediation efforts began in 1990, more than 772 million L of groundwater and approximately 3.13 million m³ of vapor have been treated, yielding about 198.3 kg of removed VOCs.

The central GSA, eastern GSA, and B830-Distal, South (B830-DISS) treatment facilities discharge to surface drainage courses. The B854-Proximal (B854-PRX) solar treatment unit/containerized wetland, B815-Distal (B815-DIS) aqueous phase granular activated carbon, and B830-Proximal, North (B830-PRXN) granular activated carbon treatment systems discharge to an infiltration trench. The other 4 treatment systems discharge to air by misting.

Table 8-5 summarizes calendar year 2001 and cumulative totals of volumes and masses of contaminants removed from groundwater and soil vapor at Site 300.

General Services Area

During 2001, the soil vapor extraction and treatment system in the central GSA dry-well source area was continuously operated and maintained to reduce VOC concentrations in soil vapors, remediate dense nonaqueous-phase liquids in the soil, and mitigate the VOC inhalation risk inside Building 875. The groundwater extraction and treatment systems in the central and eastern GSA areas were continuously operated and maintained to reduce VOC concentrations in the groundwater to drinking water MCLs, prevent further migration of the contaminant plume, and dewater the shallow water-bearing zone in the Building 875 dry-well area to enhance soil vapor extraction.



Table 8-5. Volatile organic compounds (VOCs) removed from groundwater and soil vapor at Site 300

Treatment area	Startup date	2001		Cumulative total	
		Water treated (ML) ^(a)	VOCs removed (kg)	Water treated (ML) ^(a)	VOCs removed (kg)
General Services Area					
Eastern GWTF ^(b)	1991	78.5	0.19	727.9	6.02 ^(c)
Central GWTF	1993	4.87	0.54	24.97	10.07
Building 834	1995	0.157	2.55	0.82 ^(c)	31.04 ^(c)
Building 815	1999	4.11	0.031	6.18	0.046
Building 832	1999	1.99	0.10	3.78	0.32
Building 854	1999	4.43	1.27	8.58	5.36
Pit 6	1998	— ^(d)	— ^(d)	0.268	0.0014
		Soil vapor treated (10 ³ m ³)	VOCs removed (kg)	Soil vapor treated (10 ³ m ³)	VOCs removed (kg)
General Services Area					
Central	1994	103.6	1.7	1693.6	41.28
Building 834	1998	740.3	29.41	1251.4 ^(c)	103.07 ^(c)
Building 832	1999	78.3	0.34	186.3	1.11

a ML = 1 million liters

b GWTF = Groundwater treatment facility

c Corrected from previous published values

d Groundwater treatment is not routine at Pit 6. A hydraulic pump test was conducted there in 1998.

Several monitoring wells are being considered for modification as extraction wells for the second phase of planned expansion to the groundwater extraction and treatment facility at central GSA. The addition of these extraction wells would enhance the system's ability to capture the contaminant plume and increase the mass removal.

Six new piezometers were installed in the shallow alluvium to better define the geometry and eastern GSA VOC plume. This information is to be used to guide the design of the second phase of the groundwater extraction and treatment facility expansion. It was determined that the plume is larger than previously thought, and it is anticipated

that continued monitoring of these piezometers will yield further information about the interaction of the various plumes in the GSA.

The eastern GSA treatment facility employs granular activated carbon canisters to remove VOCs from extracted groundwater. Extracted central GSA groundwater is run through an air-sparging PTU to remove VOCs. Extracted soil vapor at the central GSA is run through granular activated carbon canisters to remove VOCs.

Groundwater treated at the eastern GSA groundwater treatment facility was discharged off site to Corral Hollow Creek, in accordance with NPDES Permit No. CA0082651. During 2001, the

effluent line that conveys treated groundwater off site to the Corral Hollow Creek across private property was modified to protect the pipeline from damage due to cattle and to allow for re-use of the water by the private land owner for irrigation. The line now incorporates a diversion valve and buried or otherwise protected pipe. **Table 8-5** shows the volume of water treated and mass of VOCs removed at the eastern GSA. Influent TCE concentrations to the eastern GSA groundwater treatment system were reduced from 64 µg/L in January 1992 to 2.3 µg/L in December 2001. No longer do any off-site wells in the eastern GSA yield groundwater TCE concentrations in excess of the cleanup standard (MCL) of 5 µg/L. LLNL estimates that 2 more years of groundwater extraction and treatment will be required to achieve and maintain groundwater VOC concentrations below MCLs at the eastern GSA.

TCE concentrations in central GSA groundwater treatment system (GWTS) influent have been reduced from 9400 µg/L in 1993 to 50 µg/L in 2001. Volumes of water extracted and masses of VOCs removed from Central GSA groundwater are tabulated in **Table 8-5**. Treated groundwater continues to be discharged via misting towers, which disperse a fine mist over a large area in a remote canyon at Site 300.

Following dewatering of bedrock through groundwater extraction, soil vapor extraction and treatment of VOCs began in 1994. **Table 8-5** shows the amounts of soil vapor treated and VOCs removed at the central GSA. From 1994 through the end of 2001, total VOC concentrations in the central GSA soil vapor extraction influent stream were reduced from 450 parts per million by volume (ppmv) to 6.3 ppmv. VOC concentrations in individual central GSA soil vapor extraction wells have also been significantly reduced.

The central GSA groundwater treatment system is operating under substantive requirements for wastewater discharge issued by the Central Valley RWQCB. The eastern GSA groundwater treatment system operates under NPDES Permit No. CA0082651, issued by the Central Valley RWQCB for discharges into Corral Hollow Creek. The system operated under WDR91-052 until December 5, 1997, when WDR 97-242 was issued. Permit requirements for the central and eastern GSA groundwater treatment system are listed in **Table 8-6**. Both the central and eastern GSA treatment systems operated in compliance with regulatory requirements during 2001. LLNL submitted quarterly reports for the GSA treatment systems to the California EPA and the RWQCB in accordance with the National Pollutant Discharge Elimination System Order No. 97-242 for the eastern GSA and the Substantive Requirements for Waste Discharge for the Central GSA (Lamarre 2001i, d, k, l).

All four quarterly monitoring reports for the GSA were submitted to the EPA and RWQCB on schedule in 2001. These reports detail the performance of the treatment facilities (Lamarre 2001i, d, k, l).

Building 834 Complex

In 2001, the GWTS and soil vapor extraction (SVE) and treatment system were operated at full scale for the majority of the year. During the first and second quarters, various wellfield configurations were used to maximize VOC mass removal. Treatment facility performance under these various extraction well configurations is being evaluated to optimize cleanup operations. As mentioned previously, in situ bioremediation via reductive dechlorination of TCE occurs in areas within the Building 834 Core Area where sufficient amounts of silicon oils exist. However, it has been demonstrated that this intrinsic microbial degradation is inhibited during periods of active soil vapor



Table 8-6. General Services Area groundwater treatment system surface discharge permit requirements

Parameter	Treatment facility	
	Central General Services Area	Eastern General Services Area
VOCs	Halogenated and aromatic VOCs	Halogenated VOCs
Maximum daily	5.0 µg/L	5.0 µg/L
Monthly median	0.5 µg/L	0.5 µg/L
Dissolved oxygen	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.
pH (pH units)	Between 6.5 and 8.5, no receiving water alteration greater than ± 0.5 units	Between 6.5 and 8.5, no receiving water alteration greater than ± 0.5 units
Temperature	No alteration of ambient receiving water conditions more than 3°C	No alteration of ambient receiving water conditions more than 3°C
Place of discharge	To groundwater during dry weather and to surface water drainage course in eastern GSA canyon during wet weather.	Corral Hollow Creek
Flow rate	272,500 L/day (30-day average daily dry weather maximum discharge limit)	272,500 L/day
Mineralization	Mineralization must be controlled to no more than a reasonable increment.	Mineralization must be controlled to no more than a reasonable increment.
Methods and detection limits for VOCs	EPA Method 601—detection limit of 0.5 µg/L EPA Method 602—method detection limit of 0.3 µg/L	EPA Method 601—detection limit of 0.5 µg/L

extraction because the soil vapor extraction system draws oxygen-rich vapors into the subsurface causing the microbes to become dormant.

Because of increased operation in 2001, overall mass removal was up 69% from the previous year. During 2000, the combined groundwater and soil vapor VOC mass removal at Building 834 was 22.0 kg. During 2001, the combined VOC mass removal at Building 834 was 31.96 kg. Additional VOC mass was destroyed through in situ bioremediation; this mass removal has not been quantified.

Table 8-5 shows the amounts of water and soil vapor treated and VOCs removed at Building 834. Quarterly reports for the Building 834 treatment facility were submitted to the California EPA and the RWQCB in accordance with the Substantive Requirements for Waste Discharge (Lamarre 2001e, f, g, h). Because treated groundwater is discharged to misters and is not discharged to the ground, there are no treatment system surface discharge permit requirements for Building 834.

High Explosives Process Area

The remedial strategy for groundwater cleanup in the HE Process Area was presented in the *Draft HE Process Area Remedial Design* (RD) report (Madrid et al. 2002). This report was prepared during 2001, and submitted to the regulatory agencies in February 2002.

The HE Process Area OU is divided into three treatment areas: (1) Source Area (SRC); (2) Proximal Area (PRX); and (3) Distal Site Boundary Area (DSB). The Source Area refers to the area around Buildings 806/807, 810, 815, and 817, where the majority of confirmed contaminant releases occurred. The Proximal Area is located immediately downgradient (south) of the Building 815 Source Area in the vicinity of Buildings 818 and 823.

Contaminants, mainly TCE and the HE compound cyclo-1,3,5-trimethylene-2,4,6-trinitramine (RDX), and perchlorate reside in groundwater beneath the Source and Proximal Areas. TCE and RDX have also been detected in soil and bedrock samples collected from the vadose zone beneath the Source Area. The bulk of TCE mass in the Tnbs₂ aquifer resides beneath the Proximal Area. The Distal Site Boundary Area is located in the southern part of the HE Process Area, where the Site 300 boundary is located. This area contains TCE at low concentrations, generally below 30 µg/L. However, RDX and perchlorate are not present in the Site Boundary Area at concentrations above EPA method detection limits for those chemicals.

The remediation strategy for the HE Process Area OU is a phased, risk-based approach consistent with the Remedial Design Work Plan (RDWP) for Site 300 (Ferry et al. 2001c). In accordance with the RDWP, groundwater cleanup in the HE Process Area will be implemented in the following four phases: (1) prevent off-site migration of

groundwater contaminants; (2) minimize influence of site boundary pumping on RDX plume; (3) maximize contaminant mass removal; and (4) clean up fine-grained source areas. Phase 1 began in 1999 with the installation of a treatment facility (B815-DSB) in the Distal Site Boundary area. The purpose of this facility is to prevent off-site migration of TCE. Phase 2 began with the installation of a second treatment facility (B815-SRC) in 2000 at the Building 815 Source Area. The purpose of this facility is to begin cleanup of the TCE and RDX plumes and to minimize influence of Site Boundary pumping on upgradient plume migration. Phase 3 will begin with the installation of a third facility (B815-PRX) scheduled for installation in 2002. The primary objective of this facility is TCE mass removal. Two additional facilities, B817-SRC and B817-PRX, are planned for 2004 and 2005, respectively, as part of this phase of the cleanup effort. Phase 4, which involves cleanup of fine-grained source areas, will begin using conventional pump-and-treat techniques. If these conventional methods prove impracticable, innovative techniques, such as enhanced bioremediation, will be considered.

The proposed extraction well field for cleanup of the Tnbs₂ aquifer consists of ten extraction wells. This well field was designed using a calibrated, finite element flow and transport model, FEFLOW (Diersch 1998). The calibrated model will be used to manage and optimize the extraction well field by simulating different pumping strategies. Additional extraction wells will be added, if necessary, to achieve cleanup goals to be specified in the Final Site 300 Record of Decision (ROD).

During the past several years, different groundwater treatment technologies, including aqueous-phase granular activated carbon and bioremediation using a bioreactor were tested to evaluate their efficiency for treating RDX, perchlorate, and nitrate. Aqueous-phase granular activated carbon



was found to be cost-effective for removing RDX from groundwater, and ex situ treatment using an anaerobic bioreactor was found to be cost-effective for nitrate destruction. However, granular activated carbon was not a cost effective removal technology for perchlorate, so ion exchange will be used as a “polishing” step to remove any perchlorate remaining after granular activated carbon treatment. Discharge of treated effluent is accomplished using one of two methods: 1) a misting system to discharge to the atmosphere, or 2) an infiltration trench to discharge to the subsurface.

To date, over six million liters of groundwater have been extracted and treated by the two existing facilities (B815-DSB and B815-SRC) in the HE Process Area. As presented in [Table 8-5](#), four million liters of groundwater were extracted and treated during 2001. In addition to the removal of 0.031 kg of VOCs, 0.127 kg of RDX and 0.023 kg of perchlorate have also been removed from extracted groundwater.

Building 854 Area

Treatability studies are being conducted at the Building 854 Complex to evaluate the effectiveness of groundwater remediation techniques to achieve source control, to remediate contaminant plumes, and to assess the effect of source control on down-gradient groundwater contaminant concentrations. Treatability tests are currently being conducted at facilities in two areas: (1) adjacent to the release site of TCE at Building 854F (B854-SRC), and (2) downgradient and in the middle of the groundwater TCE plume (B854-PRX).

The Building 854 groundwater extraction and treatment system (B854-SRC), located adjacent to Building 854F, began operation on December 13, 1999. Groundwater is extracted at a rate of approximately 11 L/min from one well (W-854-02) and treated using an ion exchange unit to remove

perchlorate, followed by a solar-powered aqueous-phase granular activated carbon treatment unit (STU) to remove VOCs. Treated water is discharged from misting nozzles that atomize the treated water. The discharge point for this system is located on the hillside west of the treatment facility. The B854-SRC discharge is regulated in accordance with the Draft RWQCB Substantive Requirements for the Building 832 Canyon and Building 854 OUs.

Analytical results from treatment system influent/effluent samples, monthly volumes of water treated and discharged, and total mass of contaminants removed for the two Building 854 OU treatment facilities and treatability tests are presented in quarterly Compliance Monitoring Reports for the Building 832 Canyon and the Building 854 OUs at LLNL Site 300 (Lamarre, 2001a, b, c, d).

During 2001, more than 4.4 million L of groundwater were treated and discharged. A mass of 1.2 kg of VOCs, primarily TCE, was removed by the groundwater treatment facility operations.

The Building 854 groundwater extraction and treatment system located southeast of Building 854F (B854-PRX) began operation on November 13, 2000. Groundwater is extracted at a rate of approximately 4 L/min from one well (W-854-03). The groundwater is treated using a solar-powered aqueous-phase granular activated carbon STU to remove VOCs, and a biotreatment unit (BTU) to remove nitrate and potentially perchlorate. An ion exchange unit follows the BTU to ensure perchlorate is removed prior to discharge. The treated water is discharged to the ground via an infiltration trench located immediately south of the treatment facility. The B854-PRX discharge is regulated in accordance with the Draft RWQCB Substantive Requirements for the Building 832

Canyon and Building 854 OUs. B854-PRX typically operates only a few hours per day based on solar power availability.

During 2001, more than 708,000 L of groundwater were treated and discharged. A mass of 70 g of VOCs, primarily TCE, was removed by the groundwater treatment facility operations.

Finalization of 854 field work was the only 2001 FFA milestone for Building 854. It was completed on time by May 31, 2001.

Building 832 Canyon

The Building 832 Canyon OU Treatability Study Workplan (Ziagos and Ko 1997) sets forth plans for groundwater and soil vapor TCE extraction and treatment, using portable treatment units, solar-powered water activated-carbon treatment units, and soil vapor extraction systems. Additionally, an aboveground iron filings treatment system is being employed in the lower canyon area to treat extracted TCE-laden groundwater, destroy the TCE and degradation products, and help control the migration of the TCE plume off site.

In 1999, the Building 832 Canyon groundwater and soil vapor treatment system, B832-SRC, began continuous operation. In June 2000, the Building 830 portable groundwater treatment system (B830-PRXN) began operation. This system uses granular activated carbon treatment. An iron filings treatment unit (B830-DISS), located near the mouth of the Building 832 Canyon, was completed and began operation in July 2000. This system also included a containerized wetland unit for the treatment and removal of nitrate. In March 2001, B830-DISS was converted to treat influent water with granular activated carbon and a bioreactor. The waste discharge requirements for these facilities were finalized during 2000. **Table 8-5** shows the volume of water treated and the mass of VOCs removed in

the treatment systems. The B830-DISS treatment facility discharges to surface drainage courses; the B830-PRXN systems discharges to an infiltration trench; the B830-SRC system discharges to air by misting. Progress of the pump-and-treat systems and groundwater monitoring results are published quarterly (Lamarre 2001 a, b, c, d).

Building 850/Pits 3 and 5 Operable Unit

To determine the appropriate remediation strategy for the Pits 3 and 5 landfills, LLNL is currently conducting an evaluation of tritium, depleted uranium, and metal sources within the landfills and is continuing to build and calibrate a three-dimensional geological structural model and a finite element model of groundwater flow and contaminant transport. Additionally, LLNL is evaluating several remediation strategies to keep water from entering the landfills. These techniques include subsurface groundwater interceptor trenches, landfill freezing, and other forms of permeability reduction, and geochemical techniques to immobilize uranium in groundwater. LLNL is also conducting a water budget and field studies to elucidate how water recharges the perched water-bearing zone and enters the landfills.